

**SOCIAL COGNITION ASSESSMENT IN RELATION TO
COGNITIVE DYSFUNCTIONS AND BRAIN LESIONS
AMONG STROKE SURVIVORS**

by

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Abstract

Social cognition encompasses the outcome of a wide range of cognitive functions and processes that underlie our ability to understand and act appropriately in social situations. One common complaint made by families of brain injured patients is that ‘they have changed’—typically referring to some change in the patient’s everyday social behaviour. However, efficient instruments for the assessment of social cognitive abilities of these individuals have been lacking. To fill this gap, a novel instrument was designed to assess fifteen social cognition elements, which takes about one hour to complete. The instrument was administered to healthy controls and stroke survivors to ascertain its psychometric properties, including reliability, validity, norms progression and cut off scores.

This thesis also provides further theoretical insights into social cognition by investigation carried out in three levels: First, it aimed to identify commonalities among the social cognition elements using factor analysis. The analysis revealed four factors that explained 71% of the total variance: Social Cognition Control; Motivation; Interest in Others; and Mindreading. At the second level, the thesis addressed the associations and dissociations between social cognition elements and ‘general cognitive domains’ including executive functions, episodic memory, language and praxis. This analysis revealed that social cognition elements are mostly processed independently. However, level of education and spatial attention predicted performance on the reading of emotions task, and inhibition control predicted false belief and figurative language performance. Third, the thesis explored connectional

anatomical relationships with social cognition syndromes. Hodological analysis was conducted to explore association of social cognition performance with integrity of white matter pathways. This analysis revealed ten white matter pathways that cluster into distinct networks, and which uniquely were associated with three of the social cognition factors.

Finally, a single case study of a stroke survivor who exhibited involuntarily swearing, and suggests that inappropriate behaviour may result from impaired access to stored knowledge about social norms, perhaps due to damage to fronto-temporal connections. This case study also demonstrated degrees of convergence/divergence vis-à-vis the track-wise lesion-deficit analysis from the group study. These results speak in favour of the use of multi-faceted social cognition test battery in stroke patients, and underscore the importance of single-case studies in this population as a complement to group-based analyses.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Stroke rates have gradually been increasing over recent decades. In the United Kingdom, for example, the rates of individuals having a stroke increased by 8.4% between year 2000 and 2012 (World Health Organization, 2012). These rates were in concurrence with an increase in the numbers of the younger segment of society, namely individuals aged 20 to 65, by 25% from 1990 to 2010 worldwide (Stroke Statistics, 2015). Leaving behind national losses of energy and years of productive working contributions, as well as disabilities that place a great burden on individuals, caregivers and economic costs afforded by societies. Despite of relatively good clinical outcome, the majority (68%) of stroke-survivors suffer from difficulties in returning to work, social dysfunction and familial disturbances (Hommel et al., 2009).

One of the most successful methods to reduce these losses and address the disabilities after incidences is by accurately evaluating the damage accrued, in order to design rehabilitation plans commensurate with the physical, emotional, cognitive and social impairment. Successful social interactions are brought about by using a range of cognitive, relational and emotional abilities (Bach, Happè, Fleminger, & Powell, 2000), and plays a critical role in neurogenesis and recovery after stroke (Venna, Xu, Doran, Patrizz & McCullough, 2014).

Damage to certain brain areas are often accompanied by degraded cognitive, emotional and behavioural performance. However, according to Kleim and Jones (2008), the brain never stops learning, so in cases of brain damage, the parts of the brain that remain unimpaired, establish alternative networks “to encode new experiences and enable behavioural change”. Individuals also develop behavioural strategies to perform daily activities to compensate for lost functions. Although this sounds like a positive development, it may mean that the impaired part of the brain is

left unstimulated and less likely to be rehabilitated to the fullest extent that this is possible.

People can experience a range of cognitive problems following brain injury, including language abilities, concentration and memory. They can also encounter further difficulties that might be linked to higher cognitive and social abilities which lead to impairments in interacting with the environment, social reasoning and behaviour, understanding others' perspectives, inadequate emotional feelings and expressions. "The extent of cognitive problems in general determines how well people functionally recover after brain injuries and their ability to settle back into the community" (Humphreys et al., 2012, p. 1). From this stand point, estimating the sequelae of the damage to the abilities thought to be vital for normal behaviour is essential for early intervention care planning.

Following a brain injury, patients and carers frequently report changes in personality and social behaviour. For instance, patients may become more impulsive or aggressive—changes that have long been associated with frontal lobe dysfunction (Aron et al., 2004; Blair, 2003; Brower & Price, 2001), although the mechanisms involved remain in dispute. For example, these behaviours may be due to a disconnection in fronto-amygdala connectivity; general reduction of executive control; or a specific loss of inhibitory capacity (Derefinko, DeWall, Matze, Walsh, & Lynam, 2011).

Individuals may also misapprehend others' behaviour due to misunderstanding of their mental states such as their beliefs and intentions; alternatively they may be unable to understand how their own behaviour affects others, so their behaviour may not comply with social etiquette and expectations (Happè, Powell & Winner, 1999). Some may even retreat from social involvement due to difficulty in initiating any

spontaneous activity such as starting or sharing a conversation (Lane-Brown & Tate, 2009). It is essential to review social cognition operations in order to visualize methods to address these problems.

1.2 SOCIAL COGNITION: A THEORETICAL BACKGROUND

Social cognition refers to a set of social abilities and processes involved in analysing social psychological phenomena. Bandura (1989) presents a social cognitive theory, which revolves around the acquisition of social knowledge through the “triadic reciprocal causation model”. In his account, Bandura (1989) explains that human behaviour causation is governed by modelling process to the observed behaviour. A fundamental principal of social cognition theory in acquisition of social knowledge is “observational learning” which is believed to teach social rules and strategies of transaction in different social events and situations including behavioural patterns, judgmental standards, cognitive competencies, and generative rules for creating new forms of behaviour. The modelling is not limited to only direct observed patterns of behaviour from interpersonal relationships and media, but also from indirect forms such as written behaviour. This model is governed by four sub-functional cognitive processes as follows:

1. Attention: focusing selectively on the specific information from the surrounding stimuli to extract the relevance, complexity and the functional value of the observed behavior.
2. Retention: involves converting the observed action and their subsequent outcome to a symbol and conceptions for memory representation.

3. Production: involves reproducing the symbolic representation of the originally observed behaviour into action and adjusting future representation due to feedback from others.
4. Motivation: choosing to 'refrain from' or 're-perform' a specific action due to its expected consequences by expressing the self-satisfying and rejecting the disapproved actions.

Moreover, Bandura (1989) specifies that the modelling involves triadic reciprocal determinism which includes personal, behavioural and environmental factors. The bidirectional influence between the determinant factors considered to be the foundation of social cognition internalisation and production during the life span. The impact of each factor varies in strength as some may have stronger influence than others. Within the *personal*, which is also called the cognitive, factor are a number of components which include but not limited to knowledge, memory, attention, attribution, attitudes, expectations and cognitive schema; cognitive schema refer to a set of organized preconceived ideas that act as a framework that represents some aspect of the world. In addition to biological and other internal events that can affect perceptions and actions, the *behavioural* factor encompasses skills, practice and self-efficacy, which is the extent of self-belief in one's own ability to complete a specific assignment and reach goals (Schwarzer & Jerusalem, 1995). Finally the environmental factor includes social norms, access in community, and influence from others.

In this model the interaction between personal and behavioural factors ultimately reflect the interaction between thought, affect and action. Expectations, beliefs, self-perceptions, goals and intentions give affect behaviour. More specifically, what people think, believe, and feel affect how they behave, and how they interpret and

perceive others' intentions, thoughts and feeling may, in turn, influence their own feelings and behaviour. Individuals also create and select environment through their actions. The two way influence between behaviour and environmental factors represent how we deal with different environmental challenges and conditions in our everyday life, and in turn, how our environment is altered by every condition it creates. In summary, this "triadic causation model" (Bandura, 1989) can have diverse psychological effects that promote the development and forging of new capabilities, cognitive skills, and behaviour patterns.

Within social cognition theory, Chiavarino, Apperly, and Humphreys (2012) presented a specific model for the ability to understanding the "intention" of others based on neuroimaging evidence. According to this model, humans 'extract' a perception of the intentional behaviour of others through three distinct levels: (i) "mirroring" which involves extracting the explicit purpose of the observed conduct as it appears physically; (ii) "representation" which denotes the psychological element of the observed action, through associating a mental state believed to reflect or symbolize the observed action; and (iii) "conceptual understanding" which transcends the association of actions with a mental state, and involves the ability to associate intention with an understanding of the motivation of the observed actions and their original causes. They conclude that metalizing and mirroring systems may work independently from one another but within one system; in other words, they are interdependent.

This model is compatible with the principles of social cognitive theory in terms of epistemic internalization of social knowledge, and is applicable to the evolutionary processes of most of social cognition elements including beliefs, empathy, moral reasoning and aggression, along with underlying cognitive capabilities including executive functions and self-regulation (Bandura, 1989). However, producing belief

attribution by adults may not occur automatically (Apperly, Simpson, Riggs, Samson & Chiavarino, 2006), but on the contrary it is an effortful function that might depend on underlying cognitive abilities in order to operate normally (Samson et al., 2010).

Developmentally, social cognitive abilities develop very early in life. One of the first cognitive processes by which social knowledge is internalized is the automatic response of the mirror neurons in motor system, which enables the child to mimic other's behaviour and actions. Mirroring system involves activation to the same observed moving body parts. For example, when we see someone extend his arm to pick up a ball from the ground, the mirror neurons activity in our brain detects the observed moving body parts, as if we are doing the same action. Through this mechanism, children develop the ability to read other individuals' emotions based on non-verbal cues, such as facial expressions. Matsumoto and Hwang (2011) in their review noted a number of cross-cultural studies have clearly demonstrated the extent of humans to "read" other's basic emotions, particularly through facial expressions. The basic emotions include happiness, sadness, surprise, fear, disgust and anger. The authors suggested that this might be a biologically innate ability to aid young humans to better understand the intentions of others, as well as providing a deeper meaning of perceived actions. Facial expressions at the "macro level" may last only a fraction of a second, yet they are perceived and the meaning associated with those expressions is clearly understood. This has been validated as a universal construct.

Children's perceptual abilities during development extend beyond the facial expressions to voice tone, gestures and body language enabling them to communicate with others and understand what others might desire (Repacholi & Gopnik, 1997). And since the nature of human behaviour is often driven to achieve a specific goal, they learn to associate meanings with specific behaviour, and speculate on the

motives behind the goals. Over time they tend to employ their expertise to predict and have some expectation of others' behaviour. "Humans' unique aptitude for reasoning about mental states" is known as Theory of Mind (ToM) (Apperly, Samson, & Humphreys, 2005). This term was first presented by Premack and Woodruff (1978) to encompass the ability "to impute mental states to self and others" implicating the mind's ability to think generally about a range of mental states including knowledge, pretence, thoughts, and preference, which develops around the age of four (Gweon & Saxe, 2013). For nearly four decades after introducing the concept of ToM, many researchers have considered it as a key aspect of social cognition that enables humans to engage in complex social interaction by using a variety of visible cues (e.g., eye gaze or facial expression) or inferred cues (e.g., representations) in order to predict and explain others' behaviour and to respond to situations in a socially appropriate manner. Specifically, ToM is seen as a prerequisite for the development of more advanced socio-cognitive abilities such as the distinction between self and others' feelings, empathy, and faux pas recognition and understanding. The ability to understand that others may have feeling different than their own develop by the age of five (Bandura, 1989); empathy, which refers to the ability to express concern for the distress of others (Baron-Cohen, 2002) is continuous process that evolves throughout childhood, and which culminates with the recognition and understanding of faux pas (i.e., the ability to recognize and understand the consequences of unintended and inappropriate actions of behaviour) around 9-11 years of age (Stone, Baron-Cohen & Knight, 1998).

1.3 SOCIAL COGNITIVE DEFICITS

Social cognition is the key to the individual's social behaviour, and its integrity is dependent on functioning cognitive structures and processes involved in analysing social cognitive phenomena, such as cognitive control processes. Inefficient social cognition functioning is common after brain injuries, whether for internalizing new social competences or in re-producing social schema. Individuals may suffer from variety of interpersonal difficulties including social discomfort, frustration in social relations, failing to accomplish well-learned social skills, as well as difficulties in controlling behaviour and engaging in social events.

In terms of reproducing social knowledge, many studies linked some aspects of social cognition to higher cognitive abilities especially language and the executive functions including working memory and inhibition (Apperly, Samson & Humphreys, 2005; Baker, Peterson, Pulos & Kirkland, 2014; Henry, Phillips, Crawford, Ietswaart & Summers, 2006), however, the results were not always consistent. Satpute and Lieberman (2006) proposed a dual system of automatic- vs controlled-cognitive processes that is involved in social perception. These processes are subserved by two sets of brain regions that differentially contribute to social perception. First is the 'reflexive system', which is involved in automatic coding of the trait and evaluative implications of the observed behaviour. The automatic system is characterised by slow learning, fast operating, bidirectional, parallel-processing structures and repression of common cases. The brain regions posited for this system include: the amygdala, basal ganglia, the ventral medial prefrontal cortex (vmPFC), and the dorsal anterior cingulate cortex (daCC). Second is the 'reflective system' that is responsible for inferential goals in mind, and which takes situational constraints and other prior knowledge into account to alter the dispositional inferences drawn from observed

behaviours. The features associated with controlled operation are proposed to be fast learning, slow operating, symbolic or propositional structure, representation of abstract concepts and special cases. The brain regions posited for this system include lateral PFC, ACC, the hippocampus and the surrounding medial temporal lobe (MTL).

In order to understand social cognition deficits following stroke, researchers have attempted to explain the impact of focal and diffuse brain injury on social cognition mechanism(s), and asked a wide of range of questions such as (i) whether social cognition is an automatic or controlled process? (ii) Can social cognition operate as an independent or rather a dependant function that process as a part of higher cognition ability? (iii) Which general cognitive domain dysfunction can predict social cognition impairment? (iv) Is social cognition a unitary function or rather formed of several sub-functions? (v) Are social cognition elements associated with each other? (vi) To what extent might a deficit in a specific element (e.g. false belief understanding) have an impact on other social cognition element (e.g. emotion recognition)? And (vii) which brain regions, neural circuits and cognitive structures underlay these processes? Which neuro anatomical damage can predict social cognition impairments?

In relation to the assumption of social cognition as a unitary ability, by testing ToM as key aspect of social cognition, it can be argued that people who fail false belief tasks are expected to fail other mindreading tasks. However, evidence from some studies showed differences between the ability to attribute various mental statuses. For instance, patients' performances may vary within the same domain of social capacity such that they may manage to pass a false belief task but fail to identify a faux pas (Martín-Rodríguez & León-Carrión, 2010). Individuals may successfully determine others' intentions but fail to detect others' belief (Grèzes,

Frith, & Passingham, 2004) or emotions (Atique, Erb, Gharabaghi, Grodd, & Anders, 2011). Also a lack of correlation between tasks that purportedly measure the same construct has been reported. For example, no correlation was between the ‘reading the mind in the eyes test’ and performance on faux pas tasks (Ahmed & Miller, 2011; Muller et al., 2010). The contradictory results of such studies may be due to different mechanisms underlying elements of social cognition, particularly when separate anatomical constructs for cognitive and emotional elements of ToM have been identified (e.g., Abu-Akel & Shamay-Tsoory, 2011; Shamay-Tsoory & Aharon-Peretz, 2007).

The investigation of selective brain regions that are associated with social cognition deficits in general, ToM, intention, moral judgment and emotion recognition have been linked to the right hemisphere (Happé, Brownell & Winner, 1999; Ortigue & Bianchi-Demicheli, 2011; Yuvaraj et al., 2013), although the results of some studies reveal ToM impaired ability among patients with unilateral left hemisphere lesions (Channon & Crawford, 2000; Samson, Apperly, Chiavarino & Humphreys, 2004).

Social cognition deficits also have been associated with the frontal lobe. Rowe, Bullock, Polkey and Morris (2001), for example, investigated ToM abilities of 31 patients with unilateral frontal lobe (16 with left damage and 15 with right damage), and showed that patients’ performance was significantly impaired on both first and second false belief tasks (what one thinks vs what one thinks another thinks). Moreover, parietal and frontal lesions have been associated with impaired socio-cognitive abilities or processes that are required for socio-cognitive functioning. Within the frontal lobe, a number of sub-regions have been implicated including the frontal pole, the medial frontal cortex, the orbitofrontal cortex (OFC) and the ventral

frontal cortex (Gallagher & Frith, 2003; Grèzes, Frith, & Passingham, 2004; Shamay-Tsoory et al., 2007; Stone, Baron-Cohen & Knight, 1998; Stone & Hynes, 2011). For example, lesions to the vmPFC in particular have been linked to cognitive executive failures such as poor frustration tolerance, indecisiveness, poor judgment, lack of planning and lack of insight, as well as emotional problems such as inappropriate affect, blunted emotional experience, low emotional expressiveness, and apathy (Geraci, Surian, Ferraro & Cantagallo, 2010; Mendez, 2009; Shamay-Tsoory, 2011; Turner et al., 2007). Moreover, behavioural difficulties such as irritability, social inappropriateness and lack of initiation and persistence have also been noted (Barrash, Tranel, & Anderson, 2000). In fact, comparing patients with bilateral damage to the vmPFC with patients with brain lesions in other areas showed significantly more disturbed social behaviour, erratic decision-making and a tendency to have more diminished motivation in the vmPFC patients (Barrash et al., 2011).

With respect to parietal lesions, lesions to the temporo-parietal junction (TPJ) appear to lead to impairment in social cognitive functions, including ToM, intention and moral judgment. For example, Samson et al. (2004) examined false belief reasoning, comparing the results of two groups. The first group consisted of three stroke survivors with injuries to the left TPJ, and the second was a control group of people without such injuries. The participants were asked to carry out two types of false belief tasks: verbal and nonverbal. Stroke patients exhibited poor performance in comparison with the control group on both tasks, suggesting that the left TPJ is necessary for understanding others' beliefs.

Furthermore, Chiavarino, Apperly and Humphreys (2009) investigated the impact of frontal lobe and TPJ damage on processing intention reasoning. The performance of three groups of frontal lobe and TPJ damaged patients were compared with healthy

controls. The participants were asked at the first session to judge scenes on videos and categorize the behaviour displayed as real or false actions. Three videos were played in which real intentional, real accidental and pretend actions were shown, and the participants were asked to decide whether the actions were real or pretended. Both groups of patients, and more especially the TPJ patients, exhibited poor execution of the tasks compared to the control group in understanding deliberate lying.

Young, Camprodon, Hauser, Pascual-Leone and Saxe (2010) tested the impact of the right TPJ (rTPJ) on moral judgment. They created an artificial defect to this area by using transcranial magnetic stimulation to deactivate the neurons of the rTPJ in two experiments; before and during a situation that required moral judgment. The results of the experiment showed that the defect impacted the participants' understanding of intention. The disruption resulted in participants judging murder as morally less prohibited than a mere intention to commit an assault.

Taken together, while extant research suggests that stroke patients suffer from deficits in social cognition, it remains unclear whether these deficits are the results of a failure in cognitive control or rather due to representation difficulties. This is further compounded the fact that studies to date mostly focused on testing single or a limited number of variables (e.g. false belief, emotion recognition) assuming a unitary function, while neglecting many social cognitive components found to be impaired commonly after stroke. This has led to a scarcity in studies that take a comprehensive approach to investigating the associations/dissociations between cognitive and socio-cognitive components and how these components function after the damage caused by stroke. This is particularly important given that previous research highlights the multiplicity of dysfunctional cognitive and socio-cognitive abilities in stroke patients.

In the following sections, I summarize the critical social abilities that have direct impact on everyday life and commonly affected after stroke and which need to be covered by any social cognitive screen. From a theoretical point of view, these abilities may be classified into three categories; (1) Attribution, including identifying others intention, false belief, desire, motivation, empathy, emotion, and psychological attitudes; (2) Social knowledge, including faux pas, moral reasoning, humour, and understanding figurative language (proverbs); and (3) Neurobehavioural dysfunctions including impulsivity, anger and apathy. These critical abilities have guided the development of the social cognition screen and validation for use in stroke patients and to test further theoretical hypotheses, pertaining to the relationship between cognitive and socio-cognitive abilities and their neurobiological underpinnings.

1.4 SOCIAL COGNITION COMPONENTS

1.4.1 False Belief

False belief testing is a method used by psychologists to examine the ability of an individual to think about and respond to others' beliefs. It is believed that being able to distinguish between ones' own beliefs and others' beliefs is an indication of having "a theory of mind" ToM. In this respect, false belief has been widely investigated in terms of its development and functioning over the lifespan, its functionality in various clinical populations and chiefly within the spectra of autism and schizophrenia disorders, degenerative diseases (such and frontotemporal dementia (FTD) as well as, albeit to a lesser extent, in individuals with brain injuries including stroke and traumatic brain injuries.

The ability to distinguish between self and others' mind and beliefs has a cardinal role for the proper functioning of daily living and social interactions, as well as in teaching, learning, identifying deception and manipulating events. Internalizing social knowledge after brain injuries depends on distinguishing between self and others' beliefs, thoughts, desires, motivations and intentions as it underlies social learning and modelling (Bandura, 1989). Social knowledge is considered to be formed hierarchically upon social schemata, namely, beliefs, thoughts and information gathered from the surrounding environment. For example, holding a false belief may lead to the distortion of social schemata, which, in turn, may result in the formation of distorted social knowledge that could lead the individual exposed and in confusion. In this regard, it has been commonly reported that brain injured survivors fail false belief tasks (Apperly, Samson, Chiavarino, Bickerton & Humphreys, 2007; Apperly, Samson, Chiavarino & Humphreys, 2004; Happé, Brownell & Winner, 1999; Dennis et al., 2013; Muller et al., 2010; Samson, Apperly & Humphreys, 2007).

Neuroimaging research has shown that false belief reasoning is robustly associated with activation in the dorsal anterior cingulate cortex (dACC), the right lateral rostral PFC and the right temporo-parietal junction (R-TPJ) (Sommer, Döhnelt, Sodian, Meinhardt, Thoermer, & Hajak, 2007; Döhnelt, Schuwerk, Meinhardt, Sodian, Hajak, & Sommer, 2012), and left TPJ (L-TPJ) (Samson et al., 2004). In their review, Gallagher and Frith (2003) highlighted other areas that are consistently activated in conjunction with ToM including the anterior paracingulate cortex, the superior temporal sulci (STS) and the temporal poles bilaterally.

A study by Saxe, Schulz and Jiang (2006) in healthy adults found that both domain-general and domain-specific cognitive resources are involved in ToM. They found that brain regions involved in belief attribution also have been linked to

attention, response selection and inhibitory control. Specifically, they point out that representing beliefs and attentional reorienting within the rTPJ are in fact associated with adjacent but distinct subdivisions within the region. This result has been partly supported with a quantitative meta-analysis of 70 functional neuroimaging studies (Decety and Lamm, 2007) showing that the rTPJ plays a crucial role in processing different aspects of social cognition, as it engages during both low and higher level cognitive processes.

Taken together, most studies of false belief mechanism depended on healthy subjects, and far fewer on participants with brain injuries. Current knowledge draws on studies with small samples and case studies. To further our knowledge in the field, it is important to explore to what extent focal brain injury following stroke have impact on false belief operation, and localize the critical areas that are involved in processing. It is also important to explore whether the extent to which general cognitive domains are necessary for false belief attribution in particular socio-cognitive functions in general.

1.4.2 Emotion Reading

Emotion reading refers to the ability to identify others' emotional status by interpreting their voice, body, face expressions and gestures. It is a complex ability that merges emotion recognition and attribution abilities. Emotion recognition plays a significant role in most social skills including communication, interaction between individuals and groups, and may be a key component of other social cognitive elements such as empathy. However, there is increasing evidence suggesting that it is a function that is strongly associated with general intelligence. For example, individuals with higher IQ perform significantly better on reading the mind in the

eyes test (RMET), a task that measures one's ability to read the emotions of others from the region of the eyes (Baker, Peterson, Pulos and Kirkland, 2014).

Impairments in emotional processing can disrupt both emotion regulation and emotion perception (Newsome, Scheibel, Mayer et al., 2013; Scott, O'Donnell, & Sereno, 2012), and they are associated with impaired mood and altered emotional reactivity (Stanton, Luecken, MacKinnon & Thompson, 2013). These effects can detrimentally influence many aspects of patients' social interaction and participation. Impaired emotion recognition after stroke found to be related to a verity of interpersonal problems including expressing dissatisfaction and frustration in social relations, feelings of social discomfort, lack of desire to contact with others, feelings of social disconnection and controlling behaviours (Yuvaraj, Murugappan, Norlinah, Sundaraj & Khairiyah, 2013). Therefore, assessing the ability to read other's emotion is an essential part of a social cognition screen, which may indicate the presence of other inter- and intrapersonal problems.

A review by Yavaraj et al. (2013), covering 92 studies of post-stroke deficits, suggests that emotion recognition is not dependant on a specific brain hemisphere. Patients with frontal-lobe traumatic injuries have been shown to have significant difficulties recognizing facial emotional expressions (Callahan, Ueda, Sakata, Plamondon, & Murai, 2011). However, facial emotion recognition is a particular cognitive ability that recruits many diverse brain structures that engage at various points of time. Adolphs (2002) investigated the regular activations of these structures and proposed three stages: (1) a first stage that starts from stimulus onset to 120ms and involves activation of a 'core system' including superior colliculi, thalamus, amygdala and striate cortex; (2) the second stage lasts between 120ms and 170ms and involves activation in an 'extended system' including the striate cortex, the fusiform

gyrus (FFG), the superior temporal gyrus (STG), the amygdala, OFC, basal ganglia, hypothalamus, and brainstem; and (3) the final stage runs from 170ms to >300 ms and is based on activation of the 'cognitive emotion system' comprised of FFG, STG, OFC, somatosensory and insula (Calder, Keane, Manes, Antoun, & Young, 2000). Damage to any part in this network may lead to potential deficiency in identifying and attributing emotional states.

As far as brain-damaged patients are concerned, Adolphs, Tranel and Damasio (2003) reported on a patient who had bilateral damage to the insula, and showed substantial deficits in recognizing the facial expression of disgust, although he had preserved recognition of other facial expressions, such as fear. Woolley, Strobel, Sturm et al. (2015) found that patients with frontotemporal damage were most likely to exhibit disgusting behaviours and were, on average, the most impaired at recognizing disgust in others, or what Gallese et al. (2004: 399) called “disgust deafness”.

Turner, Paradiso, Marvel et al. (2007), using positron emission tomography (PET) with stroke patients, uncovered associations between cerebellar lesions and reduced reactions to pleasant stimuli, while they showed similar responses to frightening stimuli as healthy controls. The activity observed in relation to these stimuli in the right ventral lateral cortex and left dorsolateral PFC, amygdala, thalamus and retrosplenial cingulate gyrus was significantly lower than controls. Turner et al. (2007) found that patients with damage to the cerebellum showed some dysfunctionality in the *subjective experience* of pleasant feelings in response to happiness-evoking stimuli although the damage did not appear to affect the ability to experience unpleasant emotions. What they found was that brain systems subserving the processing of emotional material are able to adapt and develop new coping

mechanisms. Rather than processing emotions itself, the cerebellum played a coordinating role in a dynamic network of various parts of the brain, such as the amygdala and the insula, that process emotion-laden stimuli. When the cerebellum is damaged, this network develops an adaptive response by engaging alternative nodes. Turner et al. (2006) concluded that the cerebellum is a central node in the neural network underlying the subjective experience of emotion. Supporting data supplied by Schraa-Tam, Rietdijk et al. (2012) suggest that the potential role of the cerebellum in control of emotions may be relevant for goal-directed behaviour needed for observing and reacting to another person's negative expressions (such as fear or disgust) which are initiated in the amygdala and insula as discussed above.

Taken together, emotion recognition has been the focus of previous social cognition deficits following stroke research and findings provide insights for brain areas critical for this ability to operate normally. Further research could usefully explore the relationship between emotional reading and general domain processes, as well as others aspects of social cognition such as empathy, anger and desire recognition.

1.4.3 Empathy

Empathy refers to “the drive to identify emotions and thoughts in others and to respond to these appropriately” (Baron-Cohen, 2002). In another words, evaluating what another person is feeling and experiencing, and demonstrating an appropriate response. It is a selective process rather than automatic, and is a dipole function that can be evidenced through human cruelty and kindness (Baron-Cohen, 2012). Kindness encompasses activating the awareness and willingness to acknowledge how others' may feel during social interactions by adapting a ‘double-minded’ focus of attention and imagining the self in another's position. In contrast, cruelty represents

the negative tail end of a bell curve of empathy, and it occurs when empathy is switched off, and a 'single-minded' focus of attention is adopted (Baron-Cohen, 2012). Empathy increases social coherence and it is essential for successful social interaction (De Vignemont & Singer, 2006; Ioannidou & Konstantikaki, 2008), and developing interpersonal and intrapersonal relationships; developing conscience (Schinkel, 2007), permitting individuals to understand others and makes them feel valued and their feelings are protected.

Research in this area has distinguished between "cognitive empathy" which is believed to refer to the tendency towards self-awareness of others' thoughts and emotions, and "emotional or affective empathy", which refers to a specific emotional response to the subjective emotion experience of others. This emotional response ranges between sympathy (a concern felt for another in need) and compassion (the feeling that arises in witnessing another's suffering and that motivates a subsequent desire to help) (Lawrence, Shaw, Baker, Baron-Cohen & David, 2004; Goetz, Keltner, & Simon-Thomas, 2010).

Following right hemisphere stroke, particularly patients who had lesions in the temporal pole or anterior insula, were more likely to do poorly on tests of emotional and cognitive empathy (Fitzgerald, 2013). Brain-injured people have demonstrated poor performance in empathy as well as emotional recognition tests (Callahan et al., 2011; De Achával, Constanzo, Villareal et al., 2010; Hillis, 2014). Previous neuroimaging findings are inconclusive regarding hemispheric involvement in processing empathy. For instance, in comparing activation during empathy assessment between patients with left and right temporal lobe atrophy, Perry, Rosen, Kramer, Beer, Levenson and Miller (2001) linked greater empathy deficits to the right hemisphere, while Rueckert and Naybar's (2008) study on healthy subjects found that

this was limited to female performance only. However, in a lesion study, Shamay-Tsoory, Tomer, Berger and Aharon-Perez (2003) found a limited relationship between empathy deficits and the right hemisphere when the damage is restricted to the posterior regions; their findings also demonstrate the significance of empathy deficits among vmPFC lesions compared to posterior-damaged patients and healthy subjects.

Fan et al. (2011) investigated the neural underpinnings of empathy using a whole-brain based quantitative meta-analysis (MKDA) which included 40 fMRI studies. It was hypothesized that a broad core of active regions could be found during empathy task performance, and the findings highlighted the core regions that were consistently activated during empathy task performance. These regions included the supplementary motor area (SMA), the anterior insula, the anterior cingulate cortex (ACC), the mid-cingulate cortex (MCC), and the bilateral anterior insula. Authors distinguish between ‘cognitive’ and ‘affective’ empathy based on the tasks performed. For instance, in a cognitive empathy task, the subjects are required to imagine others’ feelings or evaluate the emotion from others’ perspectives, while in an emotion empathy task, subjects are required to share the emotional states of other individuals and make judgments according to others’ feelings. During cognitive empathy tasks, the dorsal aMCC is engaged more frequently, the right anterior insula has been shown to be recruited for affective empathy while the left anterior insula has been seen to operate for both forms of empathy. Fan et al. (2011) concluded that dACC, aMCC, SMA and bilateral insula can account for the network which deals with empathy.

Eres, Decety, Louis and Molenberghs 2015, provide an evidence to suggest autonomous distinction between cognitive and affective empathy. In a Voxel-Based Morphometry (VBM) study, they examined gray matter density in the neural circuits association with empathy scores, they found that cognitive and affective empathy

were represented by distinct neural circuits and structural brain regions, where higher scores on affective empathy were associated with greater gray matter density in the insula cortex and higher scores of cognitive empathy were associated with greater gray matter density in the MCC and dmPFC.

Emotional responses are, however, mediated to a large extent by the social context and the two systems will seldom work entirely independently of each other. Different neurochemical systems also appear to be involved. As a result of studies indicating that the two systems may work together, but that they may also be behaviourally, developmentally, neurochemically, and neuroanatomically dissociable.

The above studies propose potential mechanisms for cognitive and emotional empathy. In this thesis, I aim to assess cognitive and emotional empathy separately and investigate the extent to which empathy and its cognitive and affective components may be affected after stroke, as well as in relation to other social cognitive deficits. For instance, can false belief or intention recognition performance affect or be predictive of deficits in cognitive empathy? As mentioned, emotional empathy mechanism among healthy sample has been linked to the aACC a brain region that linked previously to processes of inhibitory control and attention (Saxe, Schulz & Jiang, 2006), therefore I will also investigate if this association is evidenced among post stroke survivors.

1.4.4 Intention

The term ‘intention’ often used to refer to a self-regulatory strategy for goal-directed behaviour a strategy to execute a plan that determines what, how and when a desired goal can be accomplished (Gollwitzer, 1999). Understanding others' intentions is a critical ability for social communication as it enables people to evaluate, interpret

and predict others' behaviour during social interactions in various events. For instance, when unfavourable incidence occurs and its being subject to evaluation from moral prospective, it is the capacity for mental state reasoning that enables us to distinguish between intentional harm and accident (Koster-Hale, Saxe, Dungan & Young, 2013).

Impaired intention recognition accounts for both over- and lack of metalizing, found often associated with the right hemisphere damage (RHD) (Hird & Kirsner, 2003; Krukow, 2012; Mattingley, 1999). In order to identify the underlying pragmatic reasons for impairments following RHD, Weed et al. (2010) assessed intention as a ToM-relevant ability in RHD individuals by using animated films, which, based on the film description, were divided into three categories. The first category included a description of the action only, the second involved a spoken description of the intention but without referring to the specific mental state on intention, and the last category included an ascription of the mental state. The study aimed to assess ToM by using the examinee's evaluations of the animated films. The RHD patients' performance revealed a diminished ability to differentiate between the film categories in addition to a bias towards minimizing description in the ToM film category.

In an fMRI study of healthy participants, Carter, Hodgins and Rakinson (2011) examined the processing of intention by comparing brain responses to three animated displays (using similar stimuli presented in similar starting positions but moving with different goals). In each condition, a hand moved toward one of two objects. In the first case, it picked up the object, in the second, the hand missed the object, and in the last case, it changed its path halfway to lift another object. Increased activation was observed in the right posterior superior temporal sulcus (rpSTS) for the second and third conditions reflecting the violation of the initial intention.

Other work has highlighted a network including the precuneus, the left and right posterior STS and TPJ and the medial PFC (Enrici, Adenzato, Cappa, Bara, & Teltamanti, 2011), using fMRI on healthy subjects and contrasting conditions in which tasks were designed to estimate linguistic communicative intention, gestural communicative intention, linguistic physical causality and gestural physical causality. This network was engaged independently of the modality used in communication (e.g., language, gestures), which indicates that different types of intentional information are equivalent from mental processing perspectives.

In evaluating intention recognition following focal damage caused by stroke, I examine (i) whether failing intention recognition can be related to other prospective taking abilities, such as cognitive empathy and false belief, (ii) which general cognitive domains might be linked to such deficits, and (iii) whether dysfunctional intention recognition can be linked to specific brain regions.

1.4.5 Moral Reasoning

Moral reasoning is a fundamental ability required for establishing social interactions as it helps to reserve others' entitlements, making the right decisions, and allows individuals to improve their interactions with other people.

The term 'moral reasoning' has been applied to situations which involve evaluating intentions, actions and making decisions based on the society's code of values, norms and customs in which the appropriateness of a particular conduct is determined. The principles of the morality are derived from philosophy, religion and culture. Therefore, moral standards are influenced by the characteristics of each society. Although moral standards are universally fixed throughout the ages such as the infringement of others' right, our understanding and knowledge of the limits of

moral violation are nonetheless changing over time. However, the knowledge of moral standards does not function as fixed internal regulator of conduct. Self-regulatory mechanisms do not operate unless they are activated, and there are many processes by which moral reactions can be disengaged from inhumane conduct' (Bandura, 1986; 1988c as cited in Bandura, 1989, p. 54).

Moral reasoning is a complex process draws on many social cognitive aspects and can include tests requiring either explicit or implicit knowledge of the moral norms (e.g., the social values of the society), intention (e.g., spontaneous vs. planned), motivation (e.g., social rewards, personal satisfaction), and empathy (e.g. considering what thoughts and emotions a specific action would arouse and refusing any action that cause emotional harm to others. It has been proposed that moral reasoning require an ability to infer the mental states of other individuals, which makes moral judgment potentially dependent on ToM processing (Killen, Mulvey, Richardson, Jampol, & Woodward, 2011). Although the knowledge provided about an agent's intention has a great impact on forming a moral judgment, it can be also influenced by self-beliefs as to whether the conduct itself is considered to be good or bad (Knobe, 2005). The relationship between ToM, moral reasoning and non-moral reasoning has also been demonstrated in fMRI studies. It is apparent that greater levels of activity are apparent in a 'ToM network', when moral judgements are required. It has been suggested that moral decision-making requires a greater degree of internally directed processing and representation of intentions and feelings than non-moral decision-making (Reniers, Corcoran, Völlm, Mashru, Howard & Liddle, 2012). In fMRI studies on healthy subjects, moral reasoning has been linked to a wide range of brain areas including the frontal polar, the left lateroposterior OFC, ventrolateral PFC, L-TPJ, medial thalamus and globus pallidas and bilateral inferior occipital clusters. The findings suggest a

particularly significant role for the anterior-medial PFC (amPFC) in moral decision making (Eslinger, Robinson-Long, Realmuto et al., 2009).

In general, focal brain damage to the frontal and temporal lobes affect moral reasoning among patients. In a study that compared between patients with frontotemporal dementia and stroke survivors with vmPFC damage found that both groups failed integrating intention and outcome information for moral judgment and performed significantly worse than healthy controls (Baez et al., 2014). Moreover, a study of traumatic brain injuries suggested that frontal lobe plays an essential role in social emotion processing and moral judgment (Martins, Faisca, Esteves, Muresan & Reis, 2012). The findings of Kemp et al. (2013) also suggested that OFC in particular plays a key role in moral reasoning.

Previous studies have provided some insight into the relationship between moral reasoning and other abilities. Classically, patients such as Phineas Gage have been noted as having marked moral problems after damage to the OFC (Haas, 2001), in the presence of intact intellectual abilities (Harlow, 1848, cited in, Kihlstrom, 2010). More recent studies have also suggested that problems in social cognition in patients with OFC damage can be unrelated to other cognitive deficits associated with frontal lobe function. For example, Roca et al. (2010) reported that OFC patients fail on ‘faux pas’ tests of social interaction (judging whether a statement is appropriate or inappropriate according to the social context) but not on tests of executive function, and suggested that the OFC may play a particular role in social decision-making. In addition, in a lesion study of patients with neurological and neuropsychiatric disorders, De Oliveira-Souza, Hare, Bramati et al. (2008) found that grey matter reduction in frontopolar, OFC and anterior temporal cortices, the STS and insula were

linked to high scores of psychopathy—a condition associated with altered moral sensibility.

In summary, moral reasoning is an essential function for social interactions that its impairment has been evident in various groups of patients with focal brain damage. Therefore, the assessment of moral reasoning is an important element to be included in any social cognition screens. This assessment of moral reasoning in post-stroke individuals could provide additional insights regarding its association with other cognitive and social cognitive abilities, as well as the identification of brain regions that subtend it.

1.4.6 Desire

Desire refers to that "feeling or emotion which is directed to the attainment of some object from which pleasure or satisfaction is expected" (Oxford English Dictionary, 1971). This definition suggests that desire is a concept that transcends mere like and dislike, and that it involves selecting a planned behaviour to convert the impulse into action, resulting in an expected sensation. Thus, it can be said that desire is the goal for satisfying a specific impulse (motivation) (Reiss, 2004). Understanding other peoples' mind, what they think, feel, want and intend to do is essential to comprehending their behaviour (Premack & Woodruff, 1978).

Developmentally, children acquire the ability to reason about other people's desire before developing the ability to reason about others' beliefs (Repacholi and Gopnik, 1997). Children from about 18 months of age are able to recognise desires in others and are able to distinguish between what other people want or desire, and what they do not want, whether they comply with the other person's desire. They also understand the link between desires and emotions, recognising that desired objects

cause happiness, whereas undesired objects may cause disgust (Repacholi & Gopnik, 1997). Past infancy, a greater level of understanding of the subjectivity of desires begins to appear, furthermore, they are able to distinguish between reality and pretence. Evidence from a cross cultural study shows that three years old children can pass a false belief task (Shahaeian, Peterson, Slaughter, & Wellman, 2011). It is suggested that the differences in developing belief-desire reasoning are associated with the development of cognitive abilities, specifically the executive functions. This is supported by Leslie, German and Polizzi (2005) and Apperly, Benjamin, Andrews, Grant and Todd (2011). Their studies examined belief-desire reasoning in participants between 6 years of age to adulthood, who completed simple, computer-based tests of belief-desire reasoning. They found that on belief-desire reasoning tasks, children first pass tasks involving true belief and positive desire before those involving false belief and negative desire. It was also found that participants of all ages had greater difficulty in reasoning about false belief and negative desires than true beliefs and positive desires.

Using fMRI, studies explored the brain regions related to desire in general, and whether the identified brain regions respond quantitatively to the intensity of the desire. For example, Kawadata and Zeki (2008) presented pictures of persons, objects or activities that were categorised – based on a previous pilot study – into 'desirable', 'indifference' and 'undesirable' items. The superior OFC was particularly activated by the 'desirable' stimulus, and the level of desirability was positively correlated to the activated region. In contrast, the mid-cingulate mCC and the anterior cingulate aCC cortices were linked to the 'indifference' stimulus, while no specific areas were more activated by the 'undesirable' stimulus. The link between the OFC and desire has also

been highlighted by Wang, Volkow, Telang et al. (2004) who observed increased activation in the right OFC in association with a self-reported desire for food.

Impaired desire recognition has been linked to the damage in specific brain regions. The desire recognition performance of patients with localized lesions in the vmPFC was compared to responses of patients with dorsolateral PFC lesions, mixed PFC lesions, and posterior lesions and healthy controls. The patients with vmPFC damage demonstrated the worst performance compared to the other groups (Shamay-Tsoory, & Aharon-Peretz, 2007). Moreover, Chiavarino, Apperly and Humphreys (2010) investigated the processes involved the ability to reason about others desire and intention, in three samples; parietal and frontal damaged patients, in addition to age resembled control sample. The stimuli used for assessment consisted of pictures of a game where “a man wanted to find a hidden ball in one of eight boxes. In order to get the ball (desire), the man had to first choose the box he thought contained the ball and then try to hit it by throwing a ball (intention). This design led to four conditions, in two conditions the desire and intention of the man were congruent (desire-satisfied/intention-fulfilled, desire-unsatisfied/intention-unfulfilled) and in two other conditions the desire and intention were discrepant (desire-satisfied/intention-unfulfilled, desire-unsatisfied/intention fulfilled). Participants were then asked about the desire and the intention of the man” (2010, p. 205). For example, when the man hit the box he had indicated his intention was fulfilled, while when he hit a different box, his intention was unfulfilled, and when he found the ball he wished, his desire was satisfied, while when he found a ball but with different colour, his desire was unsatisfied. Chiavarino et al. (2010) reported impaired desire processing in the frontal lobe patients where there was inconsistency between desire and intention, while damage to the TPJ was linked to frontal lobe lesions in cases where there was

inconsistency between desire and intention, and partial lobe damage – specifically, lesions to the L-TPJ – may cause critical deficits in processing desire and intention.

To sum up, the majority of research focused on the development of desire attribution, and only a limited number of studies investigated desire in individuals with brain damage. Our knowledge regarding the link between desire and other components of social cognition is limited as well as the neural networks that are critical for this ability. This thesis will investigate how desire is impacted in post-stroke patients and examine gather insight about possible neurobiological correlates.

1.4.7 Motivation

Psychological theories refer to motivation as the reason behind individuals' behaviour that usually stem from a need or a desire. Norman, Cacioppo and Berntson, (2011) explain that motivation emerged as consequence of the evolutionary development of locomotion, that is essential to decisions pertaining to what environmental stimuli to approach and what to avoid. Although motivation has been linked to our needs and desires, and which play an important role in reflexive and social behaviour, the role of motivation has not been discussed explicitly within the framework of ToM research.

Reiss (2004) based on studies that involved more than 6,000 participants, found that motivation can be synonymous with impulse. Based on his theory, he drafted a 16-desire motivation checklist as follows:

1. Power (desire to influence)
2. Curiosity (desire for knowledge)
3. Independence (desire for autonomy)
4. Status (desire for social standing)

5. Social contact (desire for peer contact)
6. Vengeance (desire to win, compete or get even)
7. Idealism (desire to improve society)
8. Physical exercise (desire to exercise muscles)
9. Romance (desire for sex and beauty)
10. Family (desire for raising own children)
11. Acceptance (desire for approval)
12. Tranquillity (desire to avoid, tranquillity or fear)
13. Saving (desire to collect)
14. Honour (desire to obey a traditional moral code)
15. Order (desire to organize) and
16. Eating (desire to consume food)

These desires differ from person to person and may be experienced and satisfied at different levels. For example, a person who has a desire for social contact might spend all night partying while another might find meeting with a few friends for a meal for one or two hours satisfies that desire. The satisfaction of each human striving is associated with an intrinsically valued feeling, such as wonder, freedom or fun, among others. Desires may nevertheless be over-satisfied. A simple example is overeating which leads to physical discomfort: the person will then usually refrain from eating anything until that feeling of discomfort abates, and the next time he eats he may eat a small meal in order not to feel overfull and bloated. The same principle applies to any of the 16 desires; and it has been found that most people aim for a moderate level of satisfaction of these desires, rather than complete satisfaction which can lead to addiction if prolonged. According to Reiss (2004), the competing theory is used to validate or explain the data. The Reiss Profile of Fundamental Goals and

Motivation Sensitivities (a desire profile according to Havercamp & Reiss, 2003) is often used to study motivational traits. Reiss (2004: 189) avers that the “16 basic desires are truly fundamental to human behaviour”. It seems apparent, therefore that these desires will lead to actions that bring about the intrinsically-valued feeling associated with the desire; for example, the desire to organise may be displayed by ensuring that a house is clean and neat in order to ensure health which results in the intrinsically valued feeling of stability. Motivation can therefore be defined as the primary psychological process that leads to forming a strategy towards obtaining a desired goal that meets the expectation of a need, seeking pleasure or avoiding pain.

Motivation could generate several plans to meet the demands of a given situation. For instance, a person who is motivated to lose weight might plan to start a specific diet or to perform some exercise at home. Individuals also may share the same motives but to varying degrees. Past experience and the strength of a motivation are important factors that influence strategy selection to sustain the behaviour toward the desired goal.

Leotti and Delgado (2011) pointed out a set of brain structures, which have been highlighted by neuroimaging research linked with reward-related activity that aids goal-directed behaviour. This network consists of cortical regions including the OFC, mPFC and subcortical regions including the caudate, putamen and nucleus. Leotti and Delgado investigated the possibility of a common neural basis for social and non-social rewards by analysing the existing neuroimaging literature. Based on categorizing the results in relation to both the main effects of reward (e.g., reward vs. punishment), and the reward value (e. g., high vs. low), individual regions have been distinguished dealing with primary (e.g., food, drink), monetary and social (e.g., charitable donations) categories. In addition, the striatum is noted to be active across

all reward types, which, they concluded, reflects the reward value to the brain irrespective of the type of reward, which they present as the 'neural currency' for motivation.

Little is known about motivation recognition after stroke. To my knowledge, there no tool that are specifically designed to assess motivation representations. Such tool is needed to examine the extent to which stroke can affect people's ability to speculate about others motivations, and how it corresponds to deficits in other aspects of social cognition. Executive functioning and whether this ability can be linked to specific brain region (s).

1.4.8 Psychological Attitudes

Psychological attitudes are a stable pattern of positive or negative appraisals of ideas (e.g. ideology), people (e.g. ethnicity) and other things related to our environment (e.g. sport). The outcome of the appraisal is believed to affect peoples' choices and to guide their immediate behaviour towards, or away from, the evaluated subject. The broad use of the term 'evaluation' is sometimes equated with 'attitude', whereas evaluation reflects the current preference of the stimulus and deciding whether in favour or disfavour, while 'attitude' can be said to be a relatively stable set of representations (Cunningham, Zelazo, Packer, & Van Bavel, 2009). The stability of an individual's attitude is believed to be modulated by the constant interaction between three factors over a period of time: (i) the cognitive factor, including beliefs, past experiences, attributes that we would associate with an object, (ii) the affective factor, including the preference and feelings linked to an attitude object, and (iii) the behavioural factor, representing the preferred reaction toward approaching the attitude subject or away from it (Breckler, 1984; Maio & Haddock, 2015).

Psychological attitude involves the creation of personal and social schemas that categorize people and things in terms of characteristics, relationships and affiliations, therefore researchers suggest that people have an adaptive attitude which is guiding the immediate behaviour -toward or away from the an object- as well as facilitate social interactions, particularly towards unfamiliar people and events, and enables individuals - who affected by past learning- to acclimatise to the world through the selection of advantageous decisions with concluded anticipation for future rewards or punishment.

There are limited studies that link social psychological attitudes and evaluative processes to their presumed neural bases. Cunningham, Haas and Jahn (2011), on the basis of reviewed neuroimaging data, proposed that attitudes are determined by activity in the OFC, the amygdala and nucleus accumbens, which provide information regarding expected outcomes.

It is evident that *attitude* is an important social cognition function that shapes and governs different aspects of our social behaviour and interactions. However, to my knowledge social and psychological attitude representation were not studied in focal brain injuries and, and more broadly there is scarcity in attitude studies with the social neurosciences. To bridge this gap, I have developed a unique task (along with a control version) that assesses this function to understand how this function is impacted following focal brain injury.

1.5 SOCIAL KNOWLEGDE COMPONENTS

1.5.1 Faux Pas

Faux pas is a situation where an individual unknowingly behaves inappropriately, leading to unintended consequence, often insulting or hurting the other's feelings.

Thus the recognition component requires the ability to infer the mental state of the actor, and an understanding of its effect on the recipient requires an empathic inference about how the recipient would feel. This test has been used widely in developmental studies as well as in populations with psychiatric disorders and focal brain damages. For example, Stone et al. (1998) assessed performance on a set of twenty stories, six containing social faux pas, and fourteen control stories that contained a minor conflict but in which no actual faux pas was committed. They compared faux pas performance between patients with bilateral damage to the OFC and patients with unilateral damage in left dPFC. The dPFC group performance was similar to the control group and detected all of the faux pas correctly, while almost all of OFC patients made errors detecting faux pas.

In a focal lesion study, Shamay-Tsoory, Tomer, Berger, Goldsher and Ahron-Prez (2005) compared the performances of three groups: patients with PFC damage, patients with posterior lesions and a group of healthy controls, on three measures of ToM: second false belief, understanding irony and distinguishing social faux pas. Damage to the right vmPFC was linked to the most impaired execution of ToM tasks particularly on irony detection and faux pas and secondly in false belief tasks. Geraci, Surian, Ferraro and Cantagallo (2010) also compared the performance of brain lesioned patients in faux pas tests and reported deficits in relation to lesions in two brain areas: the bilateral and left vmPFC and the left dPFC. Impaired performance has been connected predominantly to the left vmPFC lesions. Taken together, these results suggest that faux pas detection may not depend on domain-general executive processes associated with dPFC, but with more specific processes (e.g., concerned with the violation of social rules), and associated with more ventral and anterior lesions.

1.5.2 Figurative Language

Another element that can disrupt social communication, but not typically viewed as a language-specific deficit, is impaired use and comprehension of figurative language. The term figurative language refers to language that uses words or utterances that are literally different from their surface interpretation, and understanding figurative language has been judged to important for interactions in social contexts (Baldo, Kacinik, Moncrief, Beghin, & Dronkers, 2016). Figurative language includes proverbs and idioms (Bohrn, Altmann, & Jacobs, 2012). Proverb and metaphor interpretation, along with tasks requiring the judgment of irony have been used to assess the ability to comprehend figurative language. It is thought that grasping figurative language is dependent upon working memory (Kiang, Light, Prugh, Colson, Braff, & Kutasi, 2007) among other abilities. Proverb tests have been used to investigate the pattern of comprehension impairment in relation to figurative language. The results on this relationship to executive dysfunction (e.g., working memory, language) in different patient samples, such as alcoholic and schizophrenic patients, assist the hypothesis that their deficits stem from their inability to adopt abstract attitudes (Thoma, Hennecke, Mandok et al., 2009). It was found by Thoma et al. (2009) that schizophrenia patients chose incorrect abstract and meaningful interpretations more often and correct concrete (both meaningless and meaningful) proverb interpretations less frequently than alcohol-dependent patients and healthy controls. Compared to the alcohol-dependent group and the healthy control group, these results suggest that severe impairment of complex higher-order cognitive functions such as executive behavioural control and non-literal language comprehension may be associated with frontal lobe dysfunction. A study by Martin and McDonald (2003) supports this finding.

Moran, Nippold and Gillon (2006) investigated the relationship between working memory and comprehension of low-familiarity proverbs in adolescents with traumatic brain injury (TBI). A control group of individually age-matched peers with typical development was used in this study. In the authors' view "it is important for adolescents with traumatic brain injury (TBI) to be able to comprehend figurative language in order to experience success in social and academic contexts" (ibid., 417). Be that as it may, TBI adolescents experience difficulty in interpreting figurative language as their higher-order language skills are generally impaired. The tests, using the figurative language comprehension test of the Test of Language Competence (TLC), provided variable results with insignificant differences in performance with the control group. Language-impairment appeared to be a more significant factor in the performance differences. However, on language comprehension tests, half the participants performed below the average of the control group with the remainder performing at an age-appropriate level. Moran et al. (2006) found that working memory, which has been related to comprehension abilities in individuals both with and without brain damage, was a factor in understanding figurative language, more particularly with regard to the interpretation of proverbs. This was determined from the application of the Proverbs Comprehension Test (PCT), a task containing low-familiarity proverbs. The findings showed that there was a significant difference between the adolescents with TBI and non-TBI adolescents in terms of their overall understanding of low-familiarity proverbs, and that working memory was positively correlated with proverb comprehension. The implications of this are that TBI adolescents would experience some difficulty in performing adequately within social and academic contexts.

Kiang, Light, Prugh, Coulson, Braff and Kutas (2007) also conducted studies among schizophrenic patients on impaired proverb interpretation, which, in their view, is a hallmark of schizophrenia. They used the Delis-Kaplan Executive Function System (D-KEFS) Proverb Test and the California Verbal Learning Test (CVLT-II). The Scale for Assessment of Negative Symptoms (SANS), the Scale for Assessment of Positive Symptoms (SAPS) were used to measure both accuracy and abstraction of proverb interpretation, and the Letter-Number Span Test (LNS) was used to measure attention-dependent auditory working memory. They found that schizophrenic patients produced less accurate and less abstract descriptions of proverbs than did controls but found that impaired working memory was of greater significance than other cognitive functions such as auditory sensory-memory encoding (as indexed by the mismatch negativity (MMN), event-related brain potential (ERP); executive function; and social/occupational function, and was possibly related to generalized frontal cortical dysfunction.

Rinaldi, Marangolo and Baldassarri, (2004) investigated metaphor comprehension in 50 right-hemisphere damaged (RHD) patients and 38 control subjects using both a visuo-verbal and a verbal test. In the visuo-verbal test, participants were required to match a metaphorical sentence with one of four pictures representing the correct metaphorical meaning, the literal meaning, a control metaphor and a control literal meaning. In the verbal test, patients were asked to match a metaphorical sentence with a correct written metaphorical interpretation, a literal or a control interpretation. On both tests, the number of correct metaphorical responses in the RHD group was lower than in the control group. The visuo-verbal test appeared to be more of a challenge than the verbal test where the RHD scores were slightly higher. Of note is that when they selected the wrong response, the RHD

patients tended to select the literal answer only in the visuo-verbal test. Context did not seem to be responsible for the dissociation between the two tests. The influence of the RHD patients' major visuo-spatial deficits was also checked to exclude their role in the tendency to interpret visuo-verbal material literally. The results obtained with visual material did not appear to be connected to visuo-perceptual and/or spatial deficits.

Citing other studies an fMRI study (Calvert et al., 2001) and an MEG study (Raij et al., 2000) Rinaldi et al. (2004) conclude that the right hemisphere is involved in the integration of cross-sensory information (audio-visual information), and thus the test results appeared to be linked to an integration deficit.

Understanding the meaning behind the utterance is important ability for social communication. Assessing proverbs can thus help discern between healthy and social impaired individuals. Moreover, tests of figurative language comprehension often employ a familiar set of words that older adults often feel comfortable dealing with it. The assessment of post stroke survivors on a proverb task in conjunction with the other tasks can provide insight into the relationship between language understanding and performance on social cognitive functions.

1.5.3 Humour

Humour is an ever-present human activity that occurs in all types of social interactions, and it is considered to have a pivotal role in social interaction. It encourages positive emotions and thus can be an effective means of communication (Shiota, Campos, Keltner & Hertensetein, 2004). Post-stroke survivors often complain from changes in their sense of humour including in their ability to understand and produce jokes. Indeed, RHD patients and their spouses reported a statistically

significant decline in the patients' orientation to humour post-stroke (Heath & Blonder, 2004). This can be due to the focal damage to brain mechanism or to the disturbance affecting the underlying cognitive processes critical for humour.

Humour recognition is believed to require a higher-order cognitive ability which is reliant on both rational and social knowledge (Shammi & Stuss, 1999). Rational abilities include cognitive flexibility which enables revision of the apparent meaning of an utterance, and social knowledge to comprehend the ironies of an event or the punch line in the case of joke formation (Pérez, 2012). Humour impairments have been found to be related to ToM (in terms of belief and intention) and executive functions (working memory, set shifting and inhibition) in a sample of alcoholic subjects (Uekermann, Channon, Winkel, Schlebusch, & Daum, 2006).

Uekermann et al (2006) drew on studies that found that the frontal lobe hypothesis asserts a specific vulnerability of the PFC to the toxic effects of alcohol. A comprehensive neuropsychological test battery was administered to 29 alcoholic patients and 29 healthy controls. The test battery included measurements of executive functions, humour processing and theory of mind. In the humour processing task, the participants were presented with a series of joke stems with alternative endings (correct, slapstick, logical and illogical alternatives). It was found that the alcoholics selected a significantly lower number of correct punch lines and chose a higher number of slapstick and logical alternatives in comparison with healthy controls. In addition, alcoholic patients rated correct, slapstick and illogical alternatives as being less funny than healthy controls. The findings of the investigation thus suggest that alcoholics are impaired with respect to the cognitive component of humour processing. These findings may imply that executive functions (such as working memory) are associated with the cognitive component of humour.

What this study has shown was that the PFC plays a central role in humour processing. The results revealed cognitive humour processing deficits of alcoholics in comparison with the controls. The observed impairments were related to theory of mind and executive functions. It can, therefore, be assumed that damage to the PFC would affect humour processing in non-alcoholic TBI patients. The deficits may contribute to interpersonal problems and are thus of relevance to rehabilitation.

Wild et al. (2003) reviewed the neural correlates of humour in the literature and identified several brain areas for humour perception. These are the right frontal cortex, the vmPFC, the right and left posterior (middle and inferior) temporal regions and they also suggested a possible involvement of the cerebellum.

Shammi and Stuss (1999) showed that impairments in humour processing were mostly linked to lesions in the right frontal lobe. However, the authors suggested that cognitive processes involved in humour recognition can vary according to the kind of stimuli used in evaluations and so they may show distinct patterns. Verbal humour has been associated with verbal abstraction abilities and mental shifting, while non-verbal humour has been related to the ability to focus attention on details and to visually search the environment. The association between verbal humour and abstraction and mental shifting abilities has been confirmed by Polimeni, Campbell, Gill, Sawatzky and Reiss's (2010). In addition, a meta-analysis reviewing the neural basis of humour processing, Vrticka, Black and Reiss (2013) suggested that that humour processing recruits a large set of cortical and subcortical brain areas that maintain both the cognitive and the emotional components of humour in a stimulus modality and task-dependent manner. However, recent findings showed that humour appreciation is uniquely linked to the superior temporal gyrus (STG), and humour-comprehension responses to the left TPJ (Campbell et al., 2015).

Given evidence of significant decline the sense of humour of post stroke survivors, humour assessment is potentially an essential part of any social cognition screens. This is underscored by an overlap in brain regions associated with humour processes and social cognition more generally.

1.6 NEUROBEHAVIOURAL DYSFUNCTIONS

Apathy, anger, depression and anxiety with rates between 19% and 57% are the perhaps the most common symptoms of emotional distress often diagnosed in individuals after brain injuries irrespective of the side of lesion (Thomas & Lincoln, 2008). In this section, I present the theoretical background to these psycho-behavioural disorders. However, hence depression and anxiety are routinely assessed in hospitals using the hospital anxiety depression scale (HADS) (Zigmond & Snaith, 1983), they will not be included in the battery of tests that I intend to create. The following sections review apathy, anger and impulsivity.

1.6.1 Apathy

The emergence of this problem is common after stroke with prevalence rates ranging from 19% to 57% of the samples (Mayo, Fellows, Scott, Cameron & Wood-Dauphinee, 2009; Sagen et al., 2010). In general, post-stroke functional recovery is negatively influenced by apathy as it has been related to significant complications such as "reduced functional level, decreased response to the treatment, poor illness outcome, caregiver distress and chronicity" (Van Reekum, Stuss, & Ostrander, 2005).

Apathy is defined by Benoit, Clairet, Koulibaly, Darcourt and Robert (2004: 864) as a "lack of motivation in behaviour, cognition and affect" which is mediated by different fronto-sub-cortical circuits, and evidenced as "emotional blunting", in other

words a lack of emotional responses. It is measured by using the Apathy Evaluation Scale (AES) which was developed by Marin (1991) (as cited in Glenn, 2005) as a method for measuring apathy resulting from brain-related pathology. The Brixton Spatial Anticipation test, developed by Burgess and Shallice (1997), has also been extensively used to test apathy related to brain injury. Test studies using the Brixton test have found that apathy is related to cognitive dysfunction rather than behavioural or emotional aspects of apathy (Vordenberg., Barrett, Doninger, Contardo, & Ozoude, 2014). Andersson and Bergendalen (2002) also found that apathy was related to reduced performance on acquisition and memory, psychomotor speed, and executive functions, and not to behavioural or emotional aspects of apathy. More specifically this is related to frontal lobe dysfunction resulting in problems with divergent thinking, or flexibility and problem solving ability.

Njomboro and Deb (2014) found that apathy was not so clear cut and solely related to cognitive apathy, stating that apathy is a multifaceted and multidimensional syndrome. They identified the constructs of affective apathy and behavioural apathy which they called “subdomains of neurocognitive functioning”. In their study, they used the Emotion Hexagon test (developed by Young, Perret, Calder, Sprengelmeyer, & Ekman, 2002) which evaluates perceptions of the facial or macro-expressions used to express happiness, sadness, surprise, fear, disgust and anger to evaluate emotional apathy. They found that the influence of affective apathy symptoms on emotion perception was not significant when considered in isolation, but was significant when combined with cognitive and behavioural symptoms.

Despite Njomboro and Deb’s contestation, this appears to confirm results of the Vordenberg, et al. (2014) and the Andersson and Bergendalen (2002) studies. Njoro and Deb (2014) also investigated behavioural apathy, using the Iowa Gambling Test

(IGT) which assesses motivational decision making and performance. The IGT test was developed by Bechara, Damasio, Damasio and Anderson (1994). However, they found that the IGT did not significantly predict behavioural apathy which is evidenced by indolence and a need to prompt someone to initiate physical activity.

According to Chow, Binns, Cummings et al. (2009), this is better predicted by using 12 behavioural subscale items from the Neuropsychiatric Inventory (developed by McKann et al., 1984). Chow et al. (2009) found that the patients tested displayed concurrent affective, behavioural, and cognitive apathy symptoms, which points to further confirmation that the three domains of affective, behavioural and cognitive apathy are highly integrated and it is difficult to isolate or separate them

Apathy has been linked to frontal lobe and to bilateral basal ganglia damage in many studies; however, Hama et al. (2011) report results that support that only post-stroke apathetic depression can be linked to the damage of the bilateral basal ganglia, in both the left and right hemispheres (Andersson, 2000; Carota, Staub, & Bogousslavsky, 2002; Cummings, 1993; Robinson, 1997; Santos, Kövari, Gold, et al., 2009; Starkstein, Federoff, Price, Leiguarda, & Robinson, 1993).

Levy and Dubois (2006) investigated the functional anatomy of the prefrontal-basal ganglia system in relation to apathy. Three subtypes of disrupted processing were distinguished due to the underlying mechanisms which are responsible for apathy, and each type was related to lesions in a specific area of the brain. 'Emotional-affective apathy' was linked to orbital-medial prefrontal cortex damage or to the connected subregions (e. g., the limbic territory) within the basal ganglia (e.g., the ventral striatum and the ventral pallidum). 'Cognitive apathy' was linked to the dorsolateral prefrontal cortex and the related subregions (associative territory) within the basal ganglia (e.g., the dorsal caudate nucleus). Finally, the disruption due to

'auto-activation' was linked to the damage to the bilateral, the associative and the limbic territories of the internal portion of the globus pallidus.

1.6.2 Anger

Gross (2013) posited that anger is an emotional state that emerges as a response to a social context that has been judged by the individual as involving some form of violation, a failure to achieve a wanted goal or a situation that creates high levels of frustration. Physiologically, anger is associated with increased heartbeat, higher blood pressure and high levels of hormones which can be noticed on facial expression, body language, and tone of voice.

Anger is a natural state for all people (i.e. everyone becomes angry at some time or another) but is exacerbated by contributory physiological or psychological conditions, such as TBI or schizophrenia (Rae & Lyketsos, 2000). Kashdan, Goodman, Mallard and DeWall (2015) found that there are five anger trigger categories: other people, psychological and physical distress, intrapersonal demands, environment, and diffuse/undifferentiated/ unknown.

Ahmed, Kingston, DiGiuseppe, Bradford and Seto (2012) reported that anger has been associated with negative outcomes, including physical health problems such as myocardial ischaemia and infarction and life-threatening arrhythmias (Verrier & Mittelman, 1997), poor quality of life, interpersonal conflict and self-harm although it has also been associated with positive outcomes such as mobilizing psychological resources, facilitating perseverance, and protecting self-esteem. They cite research that has shown that anger increases one's propensity toward aggressive behavior, including intimate partner violence, child abuse, "road rage", assault and homicide.

Bilge, Kocer, Kocer and Turk Boru (2008) found that post-stroke anger (termed emotional incontinence) is related to serotonergic dysfunction in the brain.

Serotonergic dysfunction has also been found in patients with Parkinson's disease (Qamhawi, Towey, Shah et al., 2015); schizophrenia (Wyss, Hitz, Hengartner et al., 2013); and suicidality (Kim & Park, 2013). Anger clearly has major consequences for life. Gross (2013) reported that emotional regulation has been the focus of many studies in the last four decades, and that there is a distinction between problem-focused coping, which aims to solve the problem, and emotion-focused coping, which aims to decrease negative emotion experience.

In a ground-breaking study, Szasz, Szentagotai and Hofmann (2011) investigated the effects of different emotion regulation strategies (reappraisal, acceptance, and suppression) on experimentally-induced anger at the subjective and behavioural level, as measured by anger and task persistence. They used the profile of affective distress (PAD); affective style questionnaire (ASQ), attitudes and beliefs scale II (ABS-II), computerized mirror-tracing persistence task as measures to test the three constructs.

They found that suppression was the least effective and reappraisal the most effective strategy for regulating anger: participants in the reappraisal condition reported lower levels of state anger and persisted significantly longer with a frustrating task than those who were instructed to suppress or accept their negative feelings. They did, however, point out that their experiment only examined the short-term effects of different emotion regulation strategies, and that future studies should examine long-term effects in longitudinal and ecologically valid experiments.

1.6.3 Impulsivity

Impulsivity can be defined as "actions that appear poorly conceived, prematurely expressed, unduly risky, or inappropriate to the situation and that often result in undesirable consequences" (Daruna & Barnes, 1993, p.23 as cited in Giovanelli, Hoerger, Johnson & Gruber, 2013, p. 1092). It is a common problem found after brain injury, that affects one third (Hainline, Devinsky & Reding, 1992) to 56% of stroke survivors (Ghika- Schmid, van Melle, Guex & Bogousslaysky, 1999), and has been linked to right frontal lobe damage (Floden & Stuss, 2006; Floden, Alexander, Kubu, Katz & Stuss, 2008).

Impulsivity is considered to be a behavioural characteristic underlying both basic motor responses (Aron, Fletcher, Bullmore, Sahakian, & Robbins, 2003) and higher-order decision making (Moran, Lengua, & Zalewski, 2013), and can be evidence of inhibitory control deficits (Logan, Schachar & Tannock, 1997) and attention deficits (Scheffer, Monteiro, & de Almeida, 2011), which contribute to the production of a distorted social knowledge. The ability to inhibit inappropriate responses is crucial for solving both cognitive and social cognition representation, especially false belief detection (Apperly, Samson & Humphreys, 2005; Stone, 2005). Poor inhibition can also play a role in correctly attributing others' emotions, desires and visual experiences when these experiences conflict with the participant's own experiences (Samson, Apperly, Kathirgamanathan & Humphreys, 2005), although this may also be true for the rest of social cognitive elements.

Floden, Alexander, Kubu, Katz and Stuss (2008) found that impulsivity and risk taking behaviour are associated terms, although the difference between the two concepts is that impulsivity is a response to disinhibition, whilst risk-taking is linked to the reward based aspects of decision making. In their study, Floden et al. explored

the neural bases of impulsivity and risk-taking behaviour. They found that risk-taking was not a general consequence of frontal lobe damage but occurred only in patients with ventrolateral and orbitofrontal lesions. Even then, people tended to be more risk-averse than risk-taking. Poor decision-making, which can be linked to risk-taking, was detected in patients with ventromedial lesions, with laterality and the size of the lesions and gender being significant factors. Left-sided lesions appear to lead to greater levels of risk-taking behaviour, and were more pronounced in men than in women. They concluded that there was little evidence of impulsivity in a group of well-recovered patients with frontal lobe damage, that impulsivity was related more to poor calibration of stimulus-response criteria or a failure to reverse learned reward associations. In addition, behaviour tended to become more risky when reinforcement opportunities were delayed. This means that impulsive people tend to decide quickly irrespective of the consequences, while risk takers consider the consequences but they tend to under estimate them.

1.7 RESEARCH AIMS

This project aims to contribute to clinical and psychometric studies of social cognition, and to provide further theoretical insights into social cognition by studying social cognitive problems in patients after stroke. To do this, the project has four goals: (a) to develop a social cognitive screen applicable to the stroke population (Chapter 2); (b) to explore the relations between different deficits on the screen (Chapter 3); (c) to explore the relations between the deficits in the social cognitive screen and the cognitive profile of the patient (Chapter 4); and (d) to explore the relationship between social cognition and the site of the brain lesion (Chapter 5).

(a) The need for the screen and issues in screen design.

One common complaint made by friends and family of brain injured patients is that ‘they have changed’ – typically referring to some change in the patient’s everyday social behaviour in addition to difficulties in cognitive (e.g. language, attention, memory) and motor functions. In many cases, the problems in social cognition are major determiners of successful outcome of rehabilitation process (Andersson, Gunderson & Finset; 1999; Fett et al, 2011; Shimoda & Robison, 1998; Venna, Xu, Doran, Patrizz & McCullough, 2014), especially when intervention is planned at early stages (Avendano et al., 2006). Identifying impaired social cognition construct and related elements will help to generate rehabilitation plans that are specifically focused on those deficits, which is essential to enhancing the functional recovery of stroke survivors.

Currently there are no standardized measures of the social cognitions that might determine everyday behaviours and that might be affected by brain damage. Hence, there is a need, often underscored by clinicians and carers and even by patients themselves, for clinically applicable measures of social cognition that are sensitive to problems in brain-injured individuals. To date, studies evaluating social cognition in clinical populations have been largely experimental and even here there have been limitations in terms of task design, assessment of relevant domains and lack of standardization.

Regarding the task design, many studies have for example, considered ToM assessment as a key function of social cognition relying on a single task (e.g., false-belief), and considering ToM, for example, as a unitary underlying function, although there is clear evidence that ToM utilizes different cognitive mechanisms (Ahmed & Miller, 2011), within both the cognitive and affective domains of ToM (e.g., desire)

(Abu-Akel, 2003; Kalbe, Schegel, Sack et al., 2010; Shamay-Tsoory & Aharon-Peretz, 2007). Similar arguments can be made about other aspects of social cognition.

In addition, there have been few attempts to control the level of cognitive demands which are required to pass the task (high-level e.g., faux pas recognition and low-level e.g., the first false belief task) (Martín-Rodríguez & León-Carrión, 2010). Higher-level tasks are more challenging for patients so they may not pass them for reasons not related to social cognition, while they are more likely to manage to pass the lower-level tasks successfully (Apperly, Samson & Humphreys, 2005). In order to obtain more accurate results, it is recommended that specific tests should be used for each sub-process (Stone & Hynes, 2011), and control tasks should be used where possible matched for level of difficulty. Similar tasks need to be designed to be (relatively) unaffected by problems in language, visual neglect and motor performance, all of which are commonly associated with stroke. Notably we need a specially designed test instrument with minimal dependence on spatial skills, motor ability and language and which operates in a time efficient manner. Moreover, designing the social cognition tasks appropriately, factors such as working memory, the inhibitory demands of tasks, or other executive functions (Apperly, Samson & Humphreys, 2005) need to be controlled and matched for in control tasks, while the social cognition task themselves must be designed with a clear definition of the mental states to determine which specific states are tapped by various tasks (Stone, 2005).

Like most concepts in psychology, there is no consensus among researchers on the definition of each aspect of social cognition, therefore it is important to determine and define the scope of each aspect assessed in the study. A lack of theoretical content definition may result in misinterpretation of the findings and make impossible the

sampling of a set of tasks that is intended to reflect the content of given theory. In addition, these uncontrolled task demands, especially with patient groups, may result in errors in the required domain measured, for example the group may fail a ToM task because of its working memory demands (Apperly, Samson, & Humphreys, 2005; Stone et al., 1998).

A lack of standardization and group norms of measures is another limitation facing social cognitive assessment. Standard norms should provide a frame of reference that embraces a range of individual differences, something which allows the examination of the average magnitude of differences between an individual patient's performance and the average performance of healthy group of equivalent age, gender and years of education. Age-standardization could also illustrate trends of performance related to the characteristics of each age group.

(b) The relations between different aspects of social cognition

The second aim of this study is to evaluate the relationships of the social cognitive screen aspects with one another, and explore the common features and possible underlying factors. Previous investigations of some social cognitive aspects have revealed inconsistent results; for example, while significant relations have been found between empathy and emotional recognition (Lawrence et al., 2004), a lack of correlation has been reported between the 'reading the mind in the eyes test' and performance on faux pas tasks, although both are considered to reflect aspects of ToM in healthy subjects (Ahmed & Miller, 2011) and TBI samples (Muller, Simion, Reviriego et al., 2010). As stated above, most of the studies present ToM as a unitary social cognitive function associated with attributing mental states to others such as thoughts, emotions and intentions, whilst evidence from brain functional studies are in favour of partly distinct mechanisms for cognitive and emotional aspects of ToM

(Shamay-Tsoory & Aharon-Peretz, 2007), and empathy (Eres, Decety, Louis & Molenberghs, 2015). These issues can be addressed through a large-scale clinical study that assesses the associations and dissociations between tests.

In the present study, tests will be included to reflect those most typically used in the field, while some extra domains will be included in order to assess motivation and attitude attribution (both theoretically linked to social behaviour). Hence the relationships between some of the screen domains remain unknown. The relationships between the tests will be assessed using, amongst other approaches, factor analysis.

(c) The relationship between social cognition and other aspects of cognition

Another specific aim of this study is to carry out a comprehensive assessment of the relationships between poor social cognition and other aspects of cognition that can be affected in patients. Although some aspects of social cognition (e.g. false belief, apathy, emotion recognition, humour) are linked to general cognitive domain, only few previous studies have examined the relationship between more general cognitive components of cognition and aspects of social cognition. Examples here are whether poor understanding of social norms (e.g., in faux pas tests) is related to poor understanding of other concepts (e.g., tests of semantic memory more generally), or whether poor inhibitory control generally affects cognitive as well as social cognitive judgments. By measuring patients on standard cognitive as well as social cognitive tests, a better understanding of the relationships between the different aspects of social cognition and other key cognitive processes will be formed. Here patients will be assessed using the BCoS battery (Humphreys, Bickerton, Samson & Riddoch, 2012), and also with a ‘cognitive measures’ (Go/No-go task performance) of impulsivity not covered in the BCoS.

(d) Lesion localisation

The fourth aim of the study is to explore the relationships between social cognitive deficits and brain lesions. Cortical brain regions including the PFC, vmPFC, dmPFC, ACC, TPJ and STS, as well as limbic regions including the amygdala, insula, thalamus, were repeatedly empathized in previous studies as parts of neural circuits subserving aspects of social cognition (Abu-Akel & Shamay-Tsoory, 2011). This will be done using lesion-symptom mapping based on voxel-based morphological techniques. It is hoped that analysis of lesion-symptom relationships will give insights into which brain regions are involved in social cognition function(s). The correlation of the behavioural description with the quantified anatomy of the patients' lesions will provide a novel assessment of whether aspects of social cognition can be localized in the brain, or whether (e.g., due to the complexity of the processes involved) social cognition depends on widely distributed brain functions.

1.8 SUMMARY AND STRUCTURE OF THESIS

Reviewing the literature illustrated a wide range of processes underlies our ability to understand and to act appropriately in social situations. For any screen of social cognition, it will be important to capture this diversity of processes, especially as the literature indicates that many of the different processes are associated with contrasting brain regions. In this thesis, my aim is to develop a new screening tool for deficits in social cognition in brain-lesioned patients, to validate the tool against existing tests designed to assess different social cognitive processes, and to examine whether it can be used to detect abnormalities in a group of neurological patients. To this end, I have

created new assessments for many of the abilities noted above, combining them into a test battery which takes about 1 hour to complete.

In Chapter 2, the literature on the methods employed to address common social cognition difficulties arising from brain injuries, in addition significant problems that have a direct impact on everyday life is reviewed. The limitations that may occur in the assessment process will be evaluated to suggest how these challenges could be overcome. A description of the tasks and measures of the screen designed by the researcher particularly to scan social cognition abilities following stroke is provided. Then the samples of the study and the statistical methods used to extract the psychometric feature for this screen, including reliability, validity, norms progression and differences between groups are discussed.

In chapter 3, the social cognitive performance of a group of stroke survivors is analysed, in terms of its latent factors, as revealed through Factor Analysis. This is in order to evaluate the potential contribution of clusters of variables (or factors) to impairments in social cognition in this sample, and paving for analysing the relationships of social cognition factors to cognitive dysfunction and brain lesioned areas for next two chapters. Using factor analysis, the model produced four factors; social cognition control, motivation, interest in others and mindreading. The common main features of each factor are described and the relationships between the factors are discussed.

In chapter 4, cognitive processes that can affect the functioning of social cognition are discussed. The relations between social cognition aspects and general cognitive abilities in four cognitive domains include; attention and executive functions, language, episodic memory and praxis including everyday multi-step action. Using factor analysis to describe the cognitive/social cognitive syndromes

revealed seven factors, and the characteristic of each factor is described. The underlying cognitive domains that can contribute to the deficits of social cognition functions are explained, and possible cognitive predictors are detected.

In chapter 5, the anatomical associations of socio-cognitive functioning and in particular to each of the social cognition factor is investigated. Using a track-wise lesion-deficits analysis approach, the associations of the behavioural data with the quantified anatomy of the patients' lesions are analysed. The analysis revealed a unique association between distinct networks of white matter tracks and three factors of social cognition, namely; social cognition control, motivation and interest in others.

In chapter 6, a case study of a stroke survivor with apparent problems in everyday social behaviour and involuntary swearing which were not apparent before the brain lesion are presented. The stroke resulted in large cortical and subcortical lesions involving frontal and temporal lobes. Using the SCS, BCoS and OCS, his general cognitive abilities and social cognition functions is assessed. In addition to quantified lesion analysis to the anatomical regions and white matter tracks. The results of behavioural data in light of white track lesions associated with the social cognition factors were discussed.

Chapter 7, a general discussion that linked all the findings of this thesis together is presented. Including; the practical application of the screen, placing the findings in general context of social cognition studies, the impact of the findings on social cognition and neurological fields and finally the strengths and limitations of the thesis is discussed.

CHAPTER 2

THE SOCIAL COGNITION SCREEN

Synopsis

In chapter 1, I defined the different components of social cognition and discussed possible factors that contribute to the degradation of these abilities after stroke. In chapter 2, I focus on the methods applied in the literature to assess social cognition capabilities, taking into account to overcome their limitation aspects in designing the Social Cognition Screen (SCS). I strived as much as possible to design the tasks and measures to take into account post-stroke survivors' common difficulties, such as using visual scenarios rather than language, using vertical procedures to avoid neglect and using forced-choice procedures to avoid aphasia. Here I report on how these different components were incorporated into the novel screen of social cognition that forms the backbone of the thesis, along with reliability studies including internal consistency and stability over time, as well as study validity of the new tests in relation to other standard tests in the literature. Data from healthy controls in addition to stroke survivors were collected and the Social Cognition Screen (SCS) age norms were developed. The differences between healthy controls and the clinical sample on the measures of the SCS were discussed.

2.1 INTRODUCTION

Social cognition broadly refers to the outcome of the cognitive structures and processes influencing the interaction between individuals in social contexts. Socio-cognitive abilities enable us to comprehend social psychological phenomena by analysing the cognitive processes underlying these phenomena, and include, but not limited to, how people think about themselves and others, and how these perceptions, in turn, influence their behaviour.

Following stroke, patients and caregivers often report changes in their personality and social interactions. In recent decade, stroke has been on the rise among younger populations (aged 20-65) (Stroke Statistics, 2015), leaving the majority of them (68%), and despite relatively good clinical outcome, with difficulties in returning to work and to social dysfunction and familial disturbances (Hommel et al., 2009). Assessing these difficulties becomes a major issue for early intervention and rehabilitation targeted at specific problems, to help the patients overcome their handicap. Providing such a psychometric tool can also bring more insight to the theoretical aspect of social cognition functions. Various aspects of social cognition have been investigated in the cognitive neuropsychology literature, however, we are yet to build an understanding of how the different aspects of social cognition may interact with each other and correspond to the lesion area, and how this interaction may determine patients' everyday life functioning.

In this study, tasks are established to test a wide range of social cognitive competences. All tasks included in the SCS are chosen based the following principals; (a) sensitive to inter-individual differences, and denote the defected social cognitive operations commonly affected after stroke that (b) compose significant problems and have direct impact on patients' everyday life, and (c) have been shown to reliably

activate mentalizing networks in neuroimaging studies, and have been linked in prior studies with brain lesions or/and with specific impaired general cognitive domain dysfunction. The tasks have been designed to minimize effects of the more common difficulties after brain injury, more particularly language and movement disabilities. In addition, control tasks are provided to rule out contributions of basic factors (e.g., memory for the events in a social context), which could contribute to the problems in social cognition. The tasks are designed to form a screen of social cognition, generating a social profile over different underlying abilities. Finally, to interpret any pattern of performance in patients, the data from patients are compared to those from a group of healthy, age- and education- matched participants, to enable patients to be classified as having normal or abnormal social cognitive functions.

2.1.2 Background to the Screen

As social beings, individuals naturally engage in social interactions that essentially involving various degrees of difficulty. Individuals depend largely on their intellectual abilities (e.g. critical and creative thinking, social knowledge) and social skills (e.g. social communication) to overcome social problems. Social cognition studies attempt to detect people's social skills and knowledge by examining basic abilities that are thought to permit them to understand, make a decision, analyse, evaluate and judge behaviour. In this section, I review the most widely used methods to assess social cognition aspects, which were used in clinical samples.

False belief has been assessed using a wide variety of formats including figurative play, verbal stories and computerised scenarios. The tasks are typically accompanied or followed by formative comprehension questions concerning what an individual in the scenario thinks or believes. *False belief* performance shows a consistent developmental pattern, even across various countries and various task

manipulations (Wellman, Cross, & Watson, 2001). In a typical study, a participant may be required to make a judgement based on a false belief held by another person in the face of a contradictory ‘true belief’ held by the participant him or herself. The tasks presented to assess false belief can vary in their orientation, and could reflect the content of the belief, a belief about the location of a stimulus or about whether a stimulus is possessed by an individual. The level of reasoning involved can vary from first-order views about what an individual thinks to second -and higher- order views where nested attributions are required (testing someone’s understanding of the understanding a second individual might have of a third party).

False belief attribution has intrigued developmental psychology researchers, with much of the work built around ‘classic’ procedures, such as the Sally Ann task (Wimmer & Perner, 1983; Baron-Cohen, Leslie & Frith, 1985), which assesses false belief location and focuses on developmental progression and the disruption of this ability. In a typical study, the experimenter introduces two dolls saying, “This is Sally and this is Ann, Sally has a basket and Ann has a box, Sally also has a marble, she puts her marble into the basket and goes out of the room. While Sally was out, Ann takes the marble from the basket and puts it in the box and goes out. Now when Sally comes back to the room, where she does she think the marble is?” The essential principle for these experiments is that individuals have to establish a fact that their belief is false, then they have to put themselves inside the mind of another child in order to predict that child's belief. Children who project their own belief to others may lack the ability to distinguish that others have independent thinking and therefore they fail to determine the thoughts of the other agent. Other experiments were performed to assess false beliefs based on stimulus, content, possession and deception. False belief known content vs. unknown content; introducing a selected

known box (e.g. crayons box) filled with other content (e.g. candles) and asking the child: what's inside the box? The expected answer for the child is the known object (e.g. crayons), then the experimenter opens the box showing the different content to child inside the box. Then the experimenter introduces a toy figure (e.g. Teddy) saying that Teddy hasn't seen this box, he never seen it opened up, then the target question is presented: What does Teddy thinks is inside the box? And an answer contrary to the reality is regarded as reflecting a lack of ToM. Adapting the same measurement techniques placed within adults oriented scenarios is thought to be more appropriate for testing old people's ToM (Wimmer & Perner, 1983; Baron-Cohen, Leslie & Frith, 1985).

Desire studies have been discussed in a ToM framework (Repacholi & Gopnik 1997; Wellman & Liu, 2004; Wellman & Woolley, 1990). The classic experiment was performed by presenting a toy figure to a child, then showing two diverse likable items such as snacks or stickers, then asking the child about their own favourite choice, and then the experimenter gives information about the figure's preferable item which is the opposite choice to that of the child. Lastly, the child is asked about the figure's favourite choice. If the child's presents his/her own desirable item as the response, then this is interpreted as a lack of independent thinking and ToM. In contrast if the child gives the opposite answer to their own desire then this it shows that child is able to suppress his/her own drive and has a ToM.

Accumulating evidence—especially from brain imaging studies—on different aspects of mind reading, has revealed dissimilarity in processing the cognitive and affective aspects of ToM. Although these aspects both share networks linked to the attribution of others' mental states, emotional inference processing recruits an additional network (Völlm, Taylor, Richardson et al., 2006). This notion has been

supported in a lesions study comparing patients' performances on tasks stressing cognitive versus affective aspects of ToM namely "the Yoni task", where it has been argued that cognitive and affective mentalizing abilities are partly dissociable (Shamay-Tsoory & Aharon-Peretz, 2007). The latter study required the ability to judge mental states (thought and desire) based on verbal and eye-gaze cues with minimal language and executive demands. It is a computerised task that consists of 64 trials including cognitive, affective and control trials presented in first and second order conditions, each showing a cartoon outline of a face (named Yoni) and four coloured pictures of objects belonging to a single category (e.g. fruits, objects, faces) one in each corner of the computer screen, the participant is asked to point to the correct answer (the image to which Yoni is referring), based on a sentences that appears at the top of the screen and Yoni's eye gaze, to determine Yoni's mental state.

A comparable paradigm was used on brain-damaged patients to investigate the differences between the processing of desire and intention. A task was designed to allow the researcher to manipulate the fulfilment of intention and the satisfaction of *desire* to equal degrees. The findings have confirmed the disparity between desire and intention and suggested two distinct mechanisms related to two brain regions; the parietal lobes were highly linked to processing the conceptual understanding of the semantic and logical properties of intention, and while the frontal lobes were significantly linked to coordinating the notions of desire and intention when their outcome were incongruent (Chiavarino, Apperly & Humphreys, 2010).

Since the beginning of ToM studies, several measures were presented to assess other peoples' intentions. Sarfati, Hardy-Baylé, Besche and Widlocher (1997) designed the 'intention inference task' which was used in other research (such as that of Brunet, Sarfati, Hardy-Baylé & Decety, 2000). This nonverbal task consisted of 10

short comic sequential stories. Each scenario represented the intention of a character performing a direct action, and was depicted on six cards, four showing a complete story plus two distracting cards. Three cards containing an uncompleted story sequence were presented to the patient, and he/she had to choose a fourth card as relating to the story. Control questions were included to rule out potential effects of poor understanding and memory load. The authors aimed to test the ability of schizophrenic patients to recognize others intentions and the clinical pattern of action planning and disorganization. Compared with a control sample, the results showed significantly poorer performance in the patient group, with impaired intention attribution being linked to thought and speech disorganization.

Emotion recognition is a core component of emotional intelligence, and thought to be essential to develop social skills. Facial emotion recognition has been related to executive functions in general, revealing that IQ estimated scores can be a significant predictor of mastering this ability among healthy people (Ahmed & Miller, 2011). Several methods have been used to assess emotion recognition including expressions of a full face (Ekman & Friensen, 1976), parts of a face (Baron-Cohen, Wheelwright, Hill, Raste & Plumb, 2001), body expressions (Saxe, Carey & Kanwisher, 2004), vocal expression (Nowicki and Duke, 1994) and a combination of face, body and voice expression (Golan & Baron-Cohen, 2006; Banziger, Grandjean & Scherer, 2009).

The 'Reading the Mind in the Eyes Test' is psychological assessment of emotional and mental state reading based on facial expressions. The revised version of this test comprises 36 photographs of the eyes region of male and female actors, each one exhibiting a specific mental or emotional state and each provided with four forced answers. The test does not contain photos depicting basic emotions (happy, sad,

angry, fear and disgust) but more complex emotions such as stress, modesty, shame, anger, empathy and patience which can avoid ceiling effects in performance (Lawrence et al., 2004).

Impulsivity is a common problem found after brain injury, for example affecting one third of stroke survivors (Hainline, Devinsky & Reding, 1992). As discussed in Chapter 1, impulsive behaviour can be evidence of inhibitory control deficits (Logan, Schachar & Tannock, 1997; Roberts, Fillmore & Milich, 2011). Specifically, impulsive individuals are expected to fail inhibiting inappropriate responses and commit more mistakes comparing to the control group. The capability of selecting the appropriate behaviour by tendering an appropriate response and holding back an inappropriate response are both linked to inhibition control ability (Simmonds et al., 2008). Several methods have been used to estimate impulsivity including questionnaires. However, *Go/No-go* tasks presented in both simple or complex forms, are the most frequent and allow to assessing one's ability based on commitment to the rules and reaction time. Logan et al. (1997) assessed a group of students (n=136) using impulsivity questionnaire and then participated in a stop-signal experiment. Students who score high on the questionnaire performed worse comparing to others and exhibited slower estimated stop-signal reaction time, similar results from populations with pathological problems with impulse control. The simple form of this task requires participants to respond to a specific consistent stimulus, which appears on the majority of trials (67%), and to withhold their response to certain minority stimuli, while the complex task requires that the go stimulus may switch to no/go on some trials, and so places more memory demands on performance.

One other area that captured the attention of social cognition researchers is *moral judgment*. When assessing the literature on this, it is crucial to take cultural

differences into account, as the sort of morality targeted in the study can vary and significantly affect performance. Mendez (2009) drew attention to classifying morality into two categories: 'descriptive morality' indicating the moral rules derived from the values of the society in determining right and wrongs, reflecting the characteristics of a particular group, and 'normative morality' which reflects rules acknowledged worldwide.

Moral Judgment studies have placed reliance on written scenarios for assessment. Scenarios or short stories involving moral dilemmas are often followed by questions designed to reveal the participant's moral judgment about the decision taken by the main subject in the story. An example here is the dilemmas presented in **Figure 2.1** by Young, Cushman, Hauser and Saxe (2007). Using cognitive neuroscience approach, the purpose of their study was to test whether information about an agent's beliefs and the consequences of his/her actions contribute to moral judgment. The pattern of activation showed highest levels for cases of attempted harm, where protagonists were condemned for actions that they believed would cause harm to others, even though the harm did not occur. The results suggest a general role for belief attribution during moral judgment.

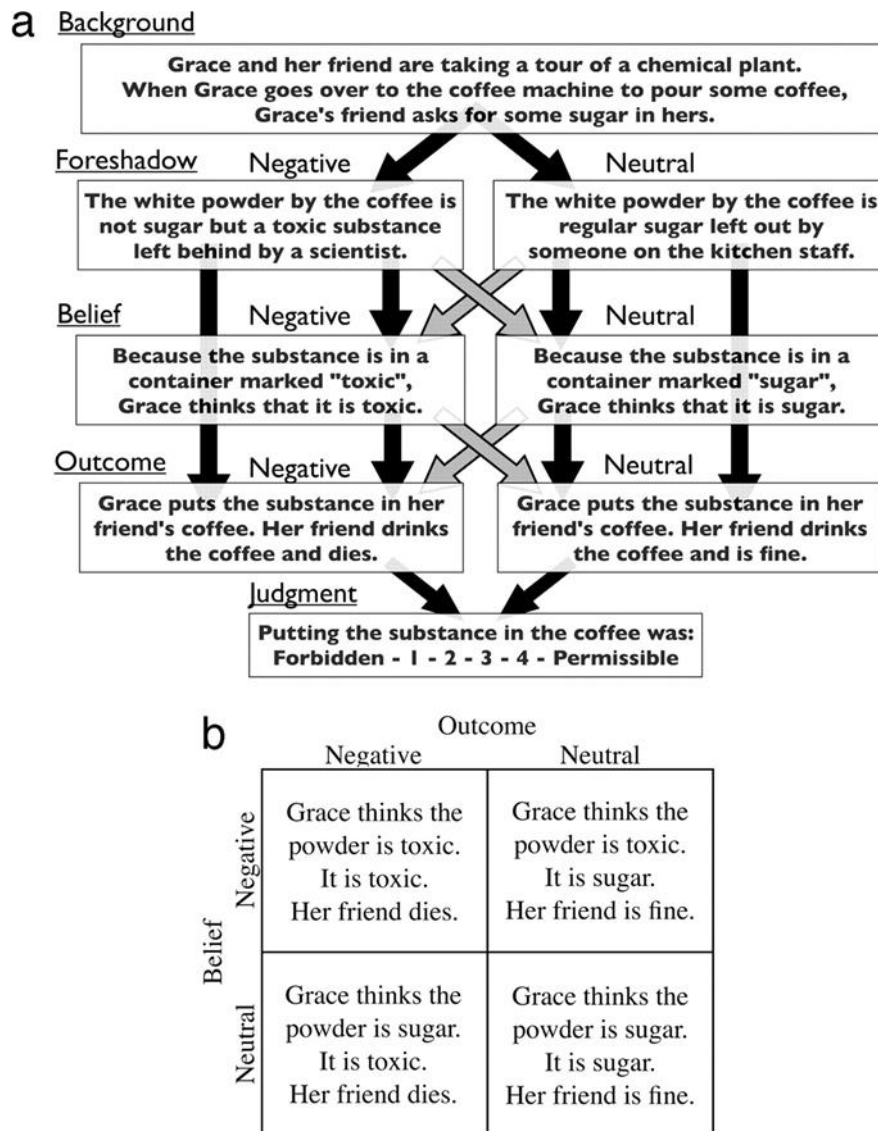


Figure 2.1 The coffee moral dilemma (from Young et al., 2007, p 8236).

2.1.3 Issues Concerning Social Cognition Assessment

Although we are beginning to learn about the neural underpinnings of social cognition, the application of this knowledge towards diagnostics and rehabilitation of impaired social cognition remains poorly developed. With two thirds of stroke survivors being at vocational age, the consequences of social cognition impairments can be disabling and have devastating impact on the rehabilitation process (Hommel et al., 2009). While some hospitals may assess post stroke survivors for potential risk of developing anxiety and depression after the incident, very often they are not

assessed on social cognitive abilities. Hence there is a need perceived by clinicians, carers and even by patients themselves for clinically applicable measures of social cognition sensitive to problems in brain injured individuals. The studies evaluating social cognition in clinical populations have been largely experimental and even here there have been limitations in terms of task design, assessment of relevant domains and lack of standardization.

Clearly, there is a need for an instrument that is specifically tailored for stroke patients, and which is minimally dependent on the patient's spatial skills, motor ability and language, and that can be administered in a time efficient manner. Importantly, it needs to also cover a wide set of social cognitive aspects which are commonly impaired after stroke. The validity of the test will obviously require standardized norms that represent a range of individual differences and which can illustrate trends of performance related to the characteristics of each normed category.

None with standing some limitations, the assessment methods which have been reviewed in the literature are considered affective and sensitive in differentiating between healthy and clinical populations. The aim of creating this screen is to also increase the efficiency of the assessment so it can more accurately detect the defected functions. For instance, the length and the complicated details and language of the moral dilemmas' scenarios can be challenging for assessing patients who often suffer from fatigue and limited attention span. Therefore, a nonverbal task would be more convenient and which can yield a more accurate assessment. Another example is reading the mind in the eyes test (RMET) (Baron-Cohen et al., 1997), the first version stimuli consisted of full face pictures displaying basic and complicated emotions and provided with two forced choices, was criticized by Baron-Cohen, Wheelwright, Hill, Raste and Plumb (2001) as the forced choice between only two response options, had

too narrow a range of scores, which led to ceiling effects as the narrow range of scores was above normal. Therefore, task sensitivity was problematic and did not allow for differentiation between experimental and control groups (Golan, Baron-Cohen, Hill & Rutherford, 2007). The revised RMET stimuli consisted of pictures of the eye region and four alternative answers account for a combination of complicated emotions and mental states, this version has been criticized for the difficulty of language used for answer alternatives which may generate bias towards the level of education (Billington, Baron-Cohen & Wheelwright, 2007), and the IQ level (Baker, Peterson, Pulos & Kirkland, 2014), also for the lack of balance between positive and negative proposed alternatives in each trial which may result in random answering. Therefore, in the current study the reading emotions task of the social cognition screen (SCS) is designed to include pictures of the eyes region, displaying all basic and more complicated emotions, four alternative answers account for two positive and two negative emotions and the answers were typed vertically to facilitate the response of the neglect patients.

2.2 GENERAL AIMS AND METHODS

Previously, an explanation has been provided as to why specific aspects of social cognition need to be incorporated into the novel Social Cognition Screen (SCS) whose aim is to increase the efficiency of the assessment and to more accurately diagnose defected functions. I also focused on the methods applied in the literature to assess social cognition capabilities, taking into account developing their strength and overcoming their limitations in designing the screens' tasks. Here, I present the tasks and measures designed to assess key aspects of social cognition, taking into account post-stroke survivors' common difficulties, such as using visual scenarios rather than

language, using vertical procedures to avoid neglect and using forced-choice procedures to avoid limitations due to aphasia. With an emphasis on developing the psychometric properties of the screen including internal consistency and stability over time, and the validity of the new tests in relation to other standard tests in the literature, norms progression and finally comparisons between the clinical sample and the healthy controls sample based on the extracted standards.

2.2.1 The Social Cognition Screen's Structure

The SCS final structure consists of 9 nonverbal and 6 verbal measures. The non-verbal tasks assess impulsivity, false belief, intention, moral reasoning, emotion reading, emotional empathy, desire, motivation and attitudes recognition. The verbal tasks assess faux pas, cognitive empathy, joke formation, proverbs comprehension, apathy and anger. In order to reduce the assessment time, the scenario of two tasks was employed to assess four aspects of social cognition including first and second false belief, descriptive and normative morality and emotional empathy.

The screen includes tasks representing different aspects of social cognition necessary for everyday functions that theoretically and previously have been linked to different processes e.g. cognitive aspects such as false belief, intention, cognitive empathy, and the emotional aspects such as emotional empathy, emotion recognition and desire. Also, the screen includes measures that assess psycho-behavioural difficulties after stroke, namely apathy and anger, as well as two novel tasks assessing motivation and psychological attitudes. The novel tasks are provided with control versions to ensure a proper assessment of their sensitivity to measuring these abilities.

2.2.2 Task Development and the Description of Tasks

2.2.2.1 The False Belief and Moral Reasoning

Four animated short films were created using the MS Office PowerPoint 2012 (Movie) program. These multiple tasks were designed to assess first and second-order false beliefs in different condition of false belief, i.e. known location vs. false belief location, a known possession vs. a false belief possession, known content vs. false belief content and known desire (action) vs. false belief double deception procedures. The duration of each film ranged between 50 and 85 seconds. During each film the participant was asked to answer five questions. Two control questions accounted for reality and memory, two assess first-order and second-order false beliefs, and a ‘descriptive’ moral reasoning question was also asked. A similar format was prepared for all the questions, and the answers were to be given verbally and written by the examiner. The total scores and number for false belief questions was 8. An Example of false belief content scenario is shown in **Appendix I-1**.

2.2.2.2 Moral and Emotional Empathy Reasoning

This multiple task was designed to assess ‘normative morality’ (Mendez, 2009) and emotional empathy in everyday scenarios. It consisted of four comic strips depicting different social events, sketched in black ink on six A5 white cards. Each task represented the moral behaviour of a character in a short comic strip. Each scenario included an incomplete story of a character in different social situations. The first set of three cards contained the body of the story, and these were shown sequentially to the participant. In order to help the participant to differentiate between own decision and the agent decision in a later step (inhibit self-perspective demands), the participants were asked, “if this situation happened to you, how would you react?”

After describing their own reaction, the second set of cards is presented. The second set of cards shows the agent performing three different reactions to end the story (one represents a good deed and the other two show negative reactions). In order to complete the task, the participant is asked to choose the most moral way to behave in such a situation; The scores obtained on this task = 4 and were combined with the former task's score to complete total of 8 scores for both moral reasoning tasks.

An example of this sample is shown in **Appendix I-2**.

2.2.2.3 Emotional Empathy Task

In adding another card to the same sequence of the moral cards, depicting an additional agent, the additional agent observes the reaction of agent to the moral situation, and is asked to infer the feelings of the observer by choosing from three forced choices. The total score = 4.

Example of this sample is shown in **Appendix I-3**.

2.2.2.4 Intention Deduction Task

Four tasks were designed to represent the intention of a character in six comic strips. The comic strips were sketched in black ink on A5 white cards. The task concluded procedures in order to help the participant distinguish between own thought and the act of agent in fact (inhibiting self-perspective demands), then participants were asked to choose the logical end from the given alternatives. The alternatives depicted the logical end, an absurd action which looked relevant to the context of the story but was in fact far from reality, and an everyday action. In another words, impaired intention recognition accounted for both over and lack of metalizing.

The total score = 4. Examples are shown in **Appendix I-4**.

2.2.2.5 Emotion Reading Task

This subtest consisted of ten photographs – five males and five females – showing the eye region with gaze direction looking forward in all stimuli. For each picture, four answer alternatives were provided which indicated four different emotional statuses (two of which were positive and two negative emotional states). These alternatives were printed vertically on A4 cards in order to reduce the effects of factors such as unilateral neglect on the task. Each picture was shown to the participant and he/she was asked to select the word that represented the emotional expression displayed in each image. The pictures contained six basic emotions (anger, sadness, happiness, disgust, surprise and fear) and four more complicated emotions (gladness, regret, kindness and pensiveness).

The total score = 10. Examples are shown in **Appendix I-5**

2.2.2.6 Desire and Motivation Recognition Task

A multiple task was designed to assess desire and motivation. This task consisted of 28 trials, 14 estimated desire and desire control and 14 measured motivation and motivation control. In these tasks, eye gaze is considered as a goal-detection function along with verbal cues presented in each trial. In addition, the task is designed to assess motivation as the incentive underlying the desire e.g. a desire for reading stemming from a motivation to gain knowledge (As well as these, seven control trials assessed basic comprehension of the tasks. The stimuli are illustrated in **Appendix I-6**.

Phase 1: To inhibit self-perspective demands, in all trials, pictures of desired objects and actions were shown to the participant who was asked about her/his own preferred of displayed object or activity in each trial (e.g., sport, gathering with friends).

Phase 2: to indicate a picture of a face with either fixed or moving eye gaze appeared at the centre of the screen along with the previous desired picture and a verbal cue at the top of the screen (e.g., John wants...). The fixed eye gaze on the specific picture was considered as a nonverbal cue for the wanted object or action. The total score=7.

2.2.2.7 Motivation Task

To estimate motivation, a task involving three phrases underlying different motivations was constructed. They appeared on the screen and the participant was asked to choose the alternative that explained why the individual depicted had a desire for this choice, and what this desire represented to the individual (e.g., food – reducing hunger, friendship – social contact), as the total score, Examples are shown in **Appendix I-6**.

2.2.2.8 Psychological Attitude Reasoning Task

This novel task was based on measuring an individual's perspective on other peoples' stable pattern of positive or negative appraisals, and how patients' perceive and evaluate others' external impressions compared to healthy controls.

This task consisted of five attitude inference tasks in the areas of exercise, knowledge, parenting, healthy food and safety. Each trial contained two comparable pictures of people in different social events, and the participant was asked to point to the image that depicted the person who had a positive attitude towards the topic and then to rate each image on a ten-point rating scale (where 0 indicated weak and 10 indicated strong attitudes). These tasks were combined with another 10 control tasks to assess the subject's basic comprehension of attitudes, in two designs of respond; reordering and choosing from multiple choices. The use of language was limited in

this task and the multiple choices were printed vertically and read to the patients. The stimuli are illustrated in **Appendix I-7**.

2.2.2.9 Go/No-Go Task

This computerized task was designed by Glyn Humphreys-University of Oxford and conducted by Keiko Kitadono, University of Birmingham. It consisted of 27 trials in which the subject had to respond to an imperative stimulus; a green square which accounted for Go trials and constituted the majority of trials (67% = 18 trials). On the remaining nine trials the green square was followed by another shape (a red circle representing the No-go trials) appearing, after the initial cue, at one of the following three intervals – 150, 200 and 250 ms, and during which the participants had to withhold their response. The response time and accuracy were used to evaluate impulsivity. The maximum total score on this task is 27.

2.2.2.10 Joke Formation Task

This task assessed the understanding and composition of humour. Five items were used consisting of one-line, incomplete jokes, with four alternative endings for each joke. The subject was instructed to select the ending word or phrase, which creates a joke from the incomplete sentence. Different endings were suggested to complete this task with logical, illogical and physical endings acting as control alternatives, as well as the correct, funny answer. The total score is 5.

Example: My wife asked me what was on the TV and I said:

(a) News (b) Flowers (c) a Cat (d✓) Dust.

2.2.2.11 Proverb Comprehension

This task was designed to assess the social comprehension of proverbs as a form of figurative language. It was a pen and paper task that consisted of 10 proverbs, in

addition to a practice trial. Each proverb was accompanied by three alternatives suggesting the proverb's meaning and these include the literal, misleading and correct meanings of the proverb. The subject was asked to choose an answer to fit the meaning of the proverb from the given alternatives. The total score = 10. The stimuli are illustrated in **Appendix II-1**

2.2.2.12 The Cognitive Empathy Indicator

Seven items were borrowed from the Empathy Quotient (EQ) (Lawrence, Shaw, Baker, Baron-Cohen & David, 2004). The items were selected after applying the whole EQ inventory on healthy controls (N=79). The total score on this sub-scale is 14. The stimuli are illustrated in **Appendix II-2**

2.2.2.13 Faux pas Recognition Test

This test was created by Stone and Baron-Cohen in 1998. It consisted of ten stories that contain social faux pas, and ten control stories that contained a minor conflict but in which no actual faux pas was committed. The stories were short and they were exposed to the participant by placing the written text in front of him/her, with the examiner reading the text clearly. Each story was followed by a set of questions clarifying why that situation was considered to be awkward (comprehension question). In addition to intention and emotion empathy questions, each of the stories was followed by two control questions that the subject had to answer at the end, whether a faux pas has taken place or not. An example is provided in **Appendix II-3**.

2.2.2.14 The Anger Indicator (AI)

An objective self-report scale was recreated to measure characteristics, attitudes and symptoms of clinical anger. This scale consisted of 8 Likert-type items, with

answer alternatives ranging from: not at all= 0, slightly= 1, somewhat= 2 and a lot= 3.

The scores are summed so that the higher scores correspond to greater level of anger.

The items measured several self domains related to anger such as: intensity, orientation, interference with cognitive and health functioning. The highest score on this scale is 24. The items are provided in **Appendix II-4**.

2.2.2.15 The Abbreviated Apathy Evaluation Scale (AAES)

This paper and pen task consisted of 9 Likert-type items measuring apathy. Items were selected from the Apathy Evaluation Scale AES (Marin et al., 1991). The total score on this scale is 36, where higher scores indicated the presence of apathy. The items are provided in **Appendix II-5**.

2.2.3 Participants

All of the tests in this work have been conducted on two samples; healthy controls and brain lesioned patients. Participant from both groups were volunteers, white English speakers.

(a) Healthy Controls Sample

This sample consisted of 100 participants [48 (48%) males and 52 (52%) females], with ages ranging from 45-85 years old ($M=66.43$, $SD=8.72$); they had received an average of 12.32 years of education. Healthy participants were willing volunteers with no history of brain lesion who signed a consent form and were recruited from either (i) the School of Psychology, University of Birmingham, participant database, or (ii) The Cognitive Neuropsychology Centre-University of Oxford, or (iii) involved in public science activity such as Brain Awareness Week at the Science Museum – Oxford, and the Community Day – University of Birmingham.

(b) Stroke Patients Sample

Patients sample consisted of 49 chronic stroke patients, [36 (73%) males and 13 (27%) females], with ages ranging from 31-91 years old ($M = 65.34$, $SD = 13.67$). They had received an average of 11.87 years of education. All patients were volunteers with anatomical lesions due to stroke with a minimum 9 months since the time of the stroke. All participants have signed a consent form, and were recruited by the Cognitive Neuropsychology Centre-University of Oxford. See **Table 2.1** for the demographics of the healthy controls and patient samples.

Table 2.1 Demographics of healthy controls and patients sample

Demographics	Controls (N=100)	Patients (N=49)
Gender (M/F)	(48/52)	(36/13)
Age ($M \pm SD$)	66.43 ± 8.72	65.34 ± 13.67
Education		
Primary & Secondary (N)	35	20
College & Non-University Diploma (N)	30	13
University degree (N)	35	14

(c) Education levels

Educational levels of the study were divided to three levels; First primary and secondary schools, second consisted of college, levels and non-university diploma, and the last composed of bachelor degree and higher education. The percentage of participants underlying each gender and age groups are shown in **table 2.2**.

Table 2.2 The percentage of the participants' education levels in each age group by gender

Gender	Males			Females		
Age groups	≤ 60	61 – 69	≥ 70	≤ 60	61 – 69	≥ 70
Education %						
Primary & Secondary	36.3	18.2	45.5	22.2	44.5	33.3
College & NUD	41.7	25.0	33.3	39.2	30.4	30.4
BA & Higher EDU	46.1	15.4	38.5	20.0	45.0	35.0

2.2.4 Procedures

The University of Birmingham Ethics Committee approved the study. Data from healthy controls were collected to assess tasks feasibility and understanding. Specifically, this was conducted to demonstrate whether individuals understand the tasks, whether the practice procedure is suitable to provide an informative introduction to the test and how the time of application can be reduced to the shortest possible time in order to take into account the health status of the patients who subsequently will be assessed on these tasks. In this phase, the tasks with weak contributions to the assessment were excluded. All statistical analyses were performed using SPSS v.21.0 (IBM Corp., Armonk, NY, USA).

2.2.4.1 The Reliability Studies

The reliability of this screen was assessed in terms of internal consistency and stability over time. The internal consistency was assessed with Cronbach's Alpha in both the control and patient groups. Stability over time was assessed using test-retest procedure for the same measure and same person. The retest was administered to the clinical sample only at least after four weeks.

2.2.4.2 The Development of Self-Reported Sub-Scales

(a) *The Cognitive Empathy Indicator*: Seven items were borrowed from the Empathy Quotient (EQ), which is a 60-item questionnaire that is designed to measure empathy in adults (Lawrence, Shaw, Baker, Baron-Cohen & David, 2004). The items were selected after administering the whole EQ inventory in healthy controls (N=79). Factor analysis was conducted and the results showed factorial features highly similar to the factors featured in the original work. Seven items, with highest factor loading, were chosen to represent cognitive empathy. The internal consistency of this sub-scale was very good (Crobach's $\alpha = 0.89$).

(b) *The Anger Indicator (AI)*: Anger Indicator items were configured through two phases of item selection from the 'Clinical Anger Scale' (CAS) (Snell, Gum, Shuck, Mosley & Hite, 1995). In phase I, the items were reduced from 84 to 21 sentences by choosing an item from each cluster and providing Likert-type answer alternatives. The two versions were administered in 30 healthy controls. In phase II, a factor analysis was conducted and the items with highest factor loadings were chosen. The sub-scale illustrated good internal consistency ($\alpha = 0.81$).

(c) *The Abbreviated Apathy Evaluation Scale (AAES)*: This paper and pen task consisted of 9 Likert-type items measuring apathy. Items were selected from the Apathy Evaluation Scale AES (Marin, Biedrzycki & Firinciogullari, 1991). A self-reported questionnaire which was applied to different clinical samples including Stroke, Alzheimer's Diseases, Hypoxic brain damage, Depression and Traumatic brain injury. Data from 73 healthy controls were analysed using factor analysis and the items with higher factor loading were chosen. The sub-scale had a high level of internal consistency ($\alpha = 0.95$).

2.2.4.3 The Validation Study

Evidence of convergent validity of the SCS was gathered from analysing the relationship between the screen's sub-tests individually and various established external measures of the same ability. A literature review on the methods that have proven effective assessment of various aspects of social cognition was conducted. The methods with better psychometric features and which were applied on clinical samples were chosen. Each subtest was presented along with the external validation version to the patient at the same session. The correlations with comparable standardised tasks are illustrated in the results section **Table 2.4**

The validation version chosen for *the Go/No-go* task was 'walk don't walk task' a subscale from a Test of Everyday Attention for children (TEA-ch) (Manly et al., 2001), which is a battery of tests developed to assess disorders of attention in children. The walk don't walk subtest assesses sustained attention and response inhibition, and predicts the reports of everyday action lapses in clinical populations (Manly, Robertson, Galloway & Hawkins, 1999). It was also found to be sensitive cognitive difficulties in individuals with post-traumatic brain injuries (Robertson et al., 1997). The measure consisted of four training and 20 main trials. The task consisted of an answer sheet depicted with paths that each was divided into 14 squares. The participant are asked to listen to a tape that plays a specific sound (Go tone) which allows the participant to move across the squares and mark each step, and another tone (No-go tone) to stop moving and remaining in the same square. The stop signal appears unexpectedly and with increasing speed in each trial (Manly et al., 2001).

Regarding *first false belief* verification, the 'Revised strange stories' (White, Hill, Happé & Frith, 2009) was chosen. This measure was used to assess ToM in clinical

groups, and is sensitive to detecting ToM deficits in individuals who generally pass other direct and simpler tasks (Happé, 1994), including in individuals with focal brain injuries, and specifically with vmPFC damage (Shammy-Tsoory & Aharon-Peretz, 2007). The test consists of short stories presented and read one by one to the participant. At the end of each story, the participant is asked to explain why the main character acted in a particular way. The stories presented in dialogues similar to the animated false belief task created in the SCS, such as double bluff, false content and false possession. With respect to *second false belief* understanding, validation was assessed in relation to the second condition of the cognitive trials from the ‘Yoni task’ (Shammy-Tsoory & Aharon-Peretz, 2007). The Yoni task has been shown to be sensitive to deficits in ToM among brain-damaged individuals (Shammy-Tsoory & Aharon-Peretz, 2007). This task involved judging mental states, thought and desire, based on verbal and eye gaze cues with minimal language and executive demands. It consists of 64 trials including cognitive, affective and control trials presented in first and second order conditions. The second order false belief trials were selected and the relation between accomplishing the Yoni second false belief and the second false belief animation task were investigated. Also, the first condition desire trials were selected and the performance was compared to the SCS *desire recognition task*.

The Intention inference task (Sarfati, Hardy-Baylé, Besche & Widlocher, 1997) was used to validate the *Intention Deduction Task* of the SCS. This task has been shown to distinguish the performance of clinical samples (schizophrenic and depressed patients) when compared to healthy control sample (Sarfati, Hardy-Baylé, Besche & Widlocher, 1997), and invokes brain areas typically activated during the processing of intentionality including the PFC and the temporal poles (Brunet, Sarfati, Hardy-Baylé & Decety, 2000). The intention inference task is a nonverbal task that

required inferring the intention of characters in short comic strips. Each comic strip consisted of three pictures, which represented an uncompleted story about a character performing a very simple action. After viewing the story, the participants were asked to choose one of three answer cards, which represent the most logical choice to complete the comic strip sequence and which would explain the motivation to perform the action. Four scenarios were chosen to analyse the validity of the SCS intention task.

The *moral reasoning task* was validated against the moral judgment task, which was created by Reniers et al. (2012) to study the neural correlates associated with the process of moral and non-moral decision-making. Unlike complicated moral dilemmas used in literature, the scenarios were short and written in a simple language to ensure understanding. In addition, the names were replaced by the letters X and Z to avoid individual associations with particular names affecting decision. The moral tasks involved the presentation of a scenario followed by a question asking participants to judge whether what someone did, or intended to do, would be ‘ok’ (e.g. X’s wife has cancer but they can’t afford the drugs to treat her. X says to his friend Z: “I am going to rob the pharmacy tonight.” Question: Is it ok for X to do this?)

Evidence of convergent validity of the SCS *Emotions Reading Task* was validated against the ‘Reading the mind the eyes test’ (RMET) (Baron-Cohen, Wheelwright, Hill, Raste & Plumb, 2001) and ‘Reading the mind in face’ test (Baron-Cohen, Wheelwright & Jolliffe, 1997). The RMET was developed at the beginning as an advanced test of ToM, to assess how well the participants can put themselves into the mind of other person and to describe their mental states. The test consisted of 36 pictures of the region of the eyes with four words as answer choices. The participants were asked to choose that word best describes the mental state conveyed in the picture. Both tests have been used widely in various clinical and healthy groups in

descriptive and functional studies. Four pictures were used for validating all the complicated emotions (e.g. decisive, regretful, glad, kind) from the RMET. Knowing that RMET stimuli do not include basic emotions alternatives, the stimuli from 'Reading the mind in face' test (Baron-Cohen, Wheelwright & Jolliffe, 1997) were used to also include the basic emotions happy, surprise, fear, sad, anger and disgust.

Emotional Empathy Task was validated using the emotional empathy items from the 'Empathy Quotient' (EQ) (Lawrence, Shaw, Baker, Baron-Cohen & David, 2004). EQ is a self-report scale designed to measure empathy. The factor structure of this measure was determined based on four reliability and validity studies. In order to use this measure for validating the emotional empathy task from the SCS, the items were selected after applying the whole EQ inventory on healthy controls (N=79). Factor analysis was conducted and the results showed factorial features highly similar to the factors features reported in the original work (Lawrence, Shaw, Baker, Baron-Cohen & David, 2004). The items with highest loadings on the emotional empathy sub-scale were chosen to calculate the validation coefficients.

The Joke Formation Task from the SCS was validated in relation to the 'Humour Cartoon Task' (Gallagher et al., 2000). This task which was used in functional as well as clinical studies (Marjoram et al., 2005) and proved to be sensitive to individual differences. The original test consisted of 63 single-image cartoon jokes, depicted with black ink on an A4 paper. Thirty-one of these were designated to be 'theory of mind cartoons' other 32 jokes were physical "slapstick" or behavioural in nature and subsequently did not require ToM capabilities for their correct interpretation. Four cartoons were chosen to validate the SCS *Joke Formation Task*. The participants were shown each joke one by one and instructed to indicate to the observer when they believed they had understood its meaning. Then they gave a short explanation of their

interpretation of the joke's meaning. Responses were scored 1 for a correct answer and 0 for an incorrect answer.

The Proverb Comprehension Task in the SCS was validated in relation to the 'Metaphor task' (Happè, 1993). This task was conducted in clinical sample (autistic patients). Metaphors and proverbs are considered different types of figurative language; metaphor is a figure of speech where the meaning is not obvious, and proverb is a saying that is commonly used and normally has some sort of wisdom. However, both metaphors and proverbs are linguistic expressions whose interpretation is nonliteral, whereby the meaning of the expression as a whole cannot be computed directly from the meaning of its constituents. As such, they both require some understanding of intentions (Happè, 1993). Ten uncompleted sentences were chosen from the study's measure, the participant was asked to choose a word from a list of target words, to finish each of 10 sentences. The list of target words contained 12 words—10 target words plus two distracter words. Participants were not prevented from using the same word twice, and no item could be worked out through a process of elimination. The correct answer was scored 1 and the false sentences were given 0.

Evidence of convergent validity for the *Anger Indicator* from the SCS was based on the 'Clinical Anger Scale' (CAS) (Snell, Gum, Shuck, Mosley & Hite, 1995). CAS is a self-report instrument designed to assess the syndrome of clinical anger within the array of psychological, physiological, affective, cognitive, motoric and behavioural symptoms, presumed to have relevance in the understanding and treatment of clinical anger. It consisted of 84 sentences divided in 21 clusters with four sentences in each cluster. The four statements in each cluster varied in symptom intensity, with more intense clinical anger being associated with the fourth statement so that higher scores corresponded to greater clinical anger (e.g., Item 1: A = I do not feel angry, B = I feel

angry, C = I am angry most of the time now, and D = I am so angry all the time that I can't stand it).

2.2.4.4 Standardisation

(a) Intergroup Differences

In order to choose the most reliable cut-off scores, the potential confounding effects of age, gender and education were evaluated. These steps are important in order to determine the most reliable frame of reference when evaluating the performance of the clinical group. To evaluate the effect of age on performance, the control-standardisation-sample was divided into three age groups: 60-year olds and younger (n=20), between 61 and 69 (n=46), and finally 70-year olds and over (n=34). With respect to gender, the performance of the females and the males of the standardisation sample was evaluated. The SCS tests were performed by roughly equal numbers of males and females (for details see **table 2.5**). Finally, the effect of education on the performance of each test was evaluated by splitting the participants into three groups of education as follows: Level I was the lower level and referred to education no more than a secondary qualification; Level II included qualifications ranging between A levels and a non-university diploma; and Level III consisted of bachelor's degree and higher education.

Given the study design a MANOVA analysis would have been desirable. However, the MANOVA requires the assumption of correlated dependent variables, and is sensitive to normality and sample size (Stahle & Wold, 1990). In addition, the MANOVA is sensitive to missing data, and thus participants with uncompleted data are excluded from the analysis, which effectively reduces the current sample size to 27 only. An imputation procedure may not be suitable for the current data given the

relatively small sample size of available data. Therefore, the analyses were conducted using a series of ANOVAs, whilst applying Bonferroni correction for multiple comparison to guard against Type-I errors.

(b) Norms Progression

The SCS tests were administered in 100 control participants. However, only 27 controls managed to finish all the measures of the SCS during one session. Therefore the number of controls was different for each the subtest as follows: Go/ No-go (n=70), false belief (n=59), intention (n=61), moral reasoning (n=56), emotion reading (n= 90), cognitive empathy (n=79), emotional empathy (n=61), desire (n=64), motivation (n=64), humour (n=86), proverbs (n=86), faux pas (n=71), anger (n=62), apathy (n=71), and attitudes (n=79).

In order to determine a diagnostic score that differentiates between impaired and intact abilities, a cut-off score for each subscale was calculated. However, due to the raw scores distribution and the limited score range for some tests, direct percentile conversion was used. The cut-off scores were fixed as 2SD and less from the sample mean using the following equation:

$$x=\mu+Z\sigma$$

where (x) was the cut-off score for the measure, (μ) was the mean of the control performance in the assessment, (σ) was the standard deviation of the controls performance in the assessment, and Z was the value from the standard normal distribution table for the 95th percentile (-1.65) which indicates difficulties.

2.2.4.5 Differences between Controls and Stroke Survivors

The need for a reliable and valid instrument capable of assessing social cognition deficits following brain injuries, led to creating the SCS, which was specifically

designed to measure an array of social psychological phenomenon. In order to determine whether the statistical criterion for the cut-off scores is defining the marked impaired social cognition elements, a comparison between controls and stroke survivors' performance was conducted.

2.3 RESULTS AND DISCUSSION

2.3.1 The Reliability Studies

(a) Internal consistency

The reliability of the tests in this battery was estimated with Cronbach's Alpha, in both the control and patient samples. In the controls group, the overall internal consistency coefficient for the 15 measures was weak ($\alpha = 0.18$) most likely due to the lack of variances among controls and ceiling effects on categorical tasks (pass/no pass), which were designed in simplified for use in stroke patients. Another reason could be the small number of participants that accomplished all the tests in this battery. Comparatively, reliability coefficients for questionnaires that have 4 answer alternatives maintained moderate to high alpha coefficients even after item reduction (e.g. cognitive empathy $\alpha = 0.9$ and apathy $\alpha = 0.71$). However, in patients sample the overall internal consistency for the 15 measures -after the abbreviated measures- maintained acceptable level ($\alpha = 0.7$).

(b) Stability over time

The stability over time of the tests was assessed among patients' sample with a test-retest procedure for the same person, with the duration between the test and the retest intervals ranging from 4 to 22 weeks. However, not all participants completed all the tests of the SCS, due to various reasons such as fatigue, moving to care home, and stroke. A

paired samples t-test was performed to assess stability on all tests. There were no significant differences between the test and retest scores, following Bonferroni correction for multiple comparisons (see **Table 2.3**). In addition, correlation coefficients between the test and retest scores ranged from 0.551 to 0.958. All measures, except on the Go/No Go task, $r=0.55$, $p<0.05$, were correlated significantly at ($p < 0.01$), (see **Table 2.3**).

2.3.2 Convergent Validity

The measures of the SCS were studied in association to tasks within SCS and various established external measures that tap similar abilities and have been applied to stroke survivors, except the novel tasks measuring motivation and attitudes. All correlations were significant at $p < 0.01$, and mostly ranged between adequate (0.57) to strong (0.96). The coefficient of one measure assessing the validity for emotional empathy was weak ($r=0.16$), but significant, which suggests that the emotional empathy task of the SCS have a measurable association with the emotional empathy items selected from the EQ. **Table 2.4** provides details on the validation tests and the correlations coefficients.

Table 2.3 Patients' group test-retest reliability

Tasks	Test				Re-test				
	Range	N	Mean	SD	Mean	SD	r	T	Sig.
Go/No-go	0-27	15	5.02	1.3	7.35	1.9	0.551*	0.17	0.87
False Belief	0-8	24	6.64	1.06	6.83	1.09	0.850**	-1.74	0.1
Intention	0-4	29	3.24	0.91	3.34	0.86	0.803**	-1.00	0.33
Moral reasoning	0-8	35	6.72	1.02	6.88	0.93	0.711**	-1.07	0.29
Emotions Reading	0-10	29	6.21	1.72	6.62	1.7	0.737**	-1.8	0.08
Emo. Empathy	0-4	26	3.23	0.91	3.31	0.68	0.918**	-1.00	0.33
Cog. Empathy	0-14	19	7.58	3.52	7.89	3.04	0.802**	-0.65	0.52
Desire	0-7	22	6.18	1.59	6.41	1.26	0.928**	-2.49	0.02†
Motivation	0-7	22	6.23	1.19	6.55	0.96	0.800**	-2.08	0.05†
High Psy. Attitude	0-10	24	8.12	1.41	7.8	1.8	0.722**	1.22	0.24
Low Psy. Attitude	0-10	24	2.92	1.6	2.83	1.3	0.681**	0.37	0.72
Humour	0-5	39	2.82	1.57	2.92	1.7	0.943**	-0.62	0.54
Proverb	0-10	23	6.05	2.8	6.11	2.45	0.917**	-0.24	0.82
Anger	0-63	19	14.0	13.35	12.58	11.86	0.905**	1.09	0.29
Apathy	0-36	17	15.69	4.88	15.88	5.4	0.958**	-0.48	0.64
Faux pas	0-60	16	44.94	15.21	47.13	13.83	0.914**	-1.7	0.11

*p < 0.05, **p < 0.01

† Bonferroni correction for multiple comparisons requires p=0.003 for significance.

2.3.3 Standardisation

2.3.3.1 Intergroup Differences

In order to choose the most reliable cut-off scores, and to exclude potential confounding effects of age, gender and education on performance of participants within the control group, differences between male and females, age groups and education levels were examined. First, a *gender* differences was examined within the control groups on all tests, based on previous studies reporting gender differences on some measures such as emotion recognition and empathy (Schulte-Rüther, Markowitsch, Shah, Fink, & Piefke, 2008). A series of Bonferroni corrected ANOVAs comparing the performance between males and females revealed no significant differences on any of the measures included in the SCS (see **Table 2.5**). This indicated that mature males and females do not differ in their performance levels on various social cognition tasks, and therefore norms segmentation based on gender was not applied.

With respect to performance differences based on *level of education*, a series of ANOVAs compared the performance of three groups (Level I, n=35; Level II, n=30; and Level III, n=35) on the various SCS measures. The ANOVA analysis also showed no significant differences between the groups on any of the SCS measures (see **table 2.6** for details). It seems that social cognition competence in healthy adults aged 45 and older is independent of their level of education, and thus these results do not support segmentations based on level of education.

Table 2.4 The SCS correlations with other standardized measures

SCS tasks	Validation task	Authors	N	r *
Go/No-go	Walk don't walk	Manley et al., 1999	25	0.68
First False belief	R-Strange stories	White, Hill, Happè, & Frith., 2009	34	0.78
Second False belief	Yoni task	Shammy-Tsoory & Aharon-Peretz, 2007	31	0.57
Intention	Intention inference task	Sarfati et al, 1997	46	0.81
Moral Judgment	Moral Judgment task	Reniers, Corcoran, Völlm, Mashru, Howard & Liddle., 2012	31	0.70
Emotions Reading	Reading mind in the eyes test	Baron-Cohen et al., 2001	43	0.80
	and Faces test	Baron-Cohen et al., 1997		
Emo. Empathy	Empathy Quotient	Lawrence et al., 2004	26	0.16
Desire	Yoni task	Shammy-Tsoory & Aharon-Peretz, 2007	27	0.91
Humor	Humor cartoon task	Gallagher, Happè, Brunswicka et al., 2000	26	0.85
Proverb	Metaphor task	Happè, 1993	29	0.82
Anger Indicator	Clinical anger scale	Snell et al., 1995	25	0.96

* All measures were correlated at $p < 0.01$

Table 2.5 Gender differences within the control group on the Social Cognition Screen measures

Measures	Males			Females			F	p
	N	mean	SD	N	mean	SD		
Impulsivity (Go/No-go)	28	25.07	2.775	42	25.26	2.187	0.103	0.750
False Belief	28	7.79	0.499	31	7.77	0.497	0.008	0.930
Intention	29	3.90	0.409	32	3.97	0.177	0.827	0.367
Moral reasoning	28	7.93	0.262	28	7.89	0.315	0.213	0.647
Emotions reading	41	8.20	1.005	49	8.18	1.236	0.002	0.962
Cog. empathy	41	8.36	3.904	46	8.78	3.169	0.276	0.601
Emo. empathy	29	3.76	0.435	32	3.72	0.457	0.121	0.729
Desire	29	7.00	0.00	35	6.60	0.736	8.550	0.005†
Motivation	29	6.93	0.371	35	6.69	0.631	3.400	0.70
Humour	41	4.61	0.586	45	4.22	0.902	5.464	0.022†
Proverbs	41	8.51	1.098	45	8.64	1.171	0.290	0.591
Faux pas	33	58.36	2.369	38	58.47	3.367	0.025	0.876
Attitudes	38	7.647	0.928	41	7.81	.6421	0.828	0.366
Anger	31	1.58	1.455	31	1.65	1.355	0.033	0.857
Apathy	33	15.12	3.380	38	13.53	3.310	4.021	0.049†

† Significant variance with Bonferroni correction for multiple comparisons;

Threshold ($p = 0.003$)

Finally, the differences between *age groups* were investigated. The Bonferroni corrected ANOVA analyses revealed significant difference in humour, measured by joke formation task ($F(2,83)=7.997, p=0.001$). The Scheffe Post hoc results indicated that the mean differences for the last and the first age groups (>70 and <60) was significant ($I-J=-0.850, SD\ Error=0.22, p=0.001$), such that increase in age was associated with significantly worst humour appreciation. However, the mean differences for the last and middle age groups (>70 and $61-69$) was not significant ($I-J= -0.468, SD\ Error=0.177, p=0.035$). Overall, there results indicated that people tend to lose their sense of humour as they age (see **table 2.7** for more details).

Table 2.6 Performance differences on the Social Cognition Screen within the control group based on level of education

Measures	Education levels										
	I Primary & Secondary			II College & Non uni. Diploma			III Bachelor Degree & above				P
	n	Mean	SD	n	Mean	SD	n	Mean	SD	F	
Go/No-go	20	24.70	3.045	26	25.42	2.403	24	25.33	1.834	0.565	0.571
False belief	19	7.79	0.535	18	7.78	0.548	22	7.77	0.429	0.006	0.994
Intention	19	3.89	0.459	21	3.95	0.218	21	3.95	0.218	0.221	0.802
Moral reasoning	18	7.89	0.323	17	7.94	0.243	21	7.90	0.301	0.147	0.864
Emotion reading	31	7.87	1.024	28	8.14	1.268	31	8.55	1.028	2.938	0.058†
Cog. Empathy	27	8.70	2.866	28	8.07	3.711	24	9.13	3.860	0.603	0.550
Emo. Empathy	19	3.68	0.478	21	3.76	0.436	21	3.76	0.436	0.195	0.823
Desire	24	6.83	0.482	20	6.75	0.639	20	6.75	0.639	0.153	0.859
Motivation	24	6.83	0.482	20	6.90	0.308	20	6.65	0.745	1.166	0.318
Humour	31	4.32	0.702	27	4.43	0.879	28	4.48	0.802	0.304	0.739
Proverb	31	8.48	1.208	26	8.69	1.123	29	8.59	1.086	0.236	0.790
Faux pas	26	58.46	2.549	24	58.04	3.82	21	58.81	2.182	0.382	0.684
Anger	23	1.57	1.308	22	1.59	1.297	17	1.71	1.687	0.052	0.949
Apathy	26	14.31	3.927	23	14.00	2.828	22	14.50	3.461	0.120	0.887
P. Attitudes	26	7.54	1.02	28	7.80	0.602	25	7.848	0.697	1.133	0.327

*Significant variance with Bonferroni correction for multiple comparisons; threshold ($p = 0.003$)

2.3.3.2 Norms Progression and cut-off Scores

Norms Progression was conducted using direct percentile conversion formula. The cut-off scores were calculated and fixed at 2SD and less from the sample mean, and the progression of cut-off scores was smoothed across the three age groups. **Table 2.8** displays the scores' range, means and cut-off scores developed for all the tasks in each age group to distinguish individuals falling below the fifth percentile based on standardised residual scores. Generating age group cut off scores was necessary as the results of the age group comparisons showed significant differences on the joke formation task in addition to marginal boundary scores for four measures that their confidence levels ranged between (0.09 and 0.02). However, while these values are bigger than the Bonferroni corrected p-value, a bigger sample size may yield these differences significant as would be predicted by the acknowledge age-related decline in social cognition (Stanley, Lohani & Isaacowitz, 2014). The reported cut offs differ according to the age group for most of the measures, to account for the influence of age on individuals' social cognition outcome.

Table 2.7 Age groups differences in performance on the Social Cognition Screen among control group.

Age groups											
≤60			61-69			≥70					
Measures	n	Mean	SD	n	Mean	SD	n	Mean	SD	F	P
Go/No-go	14	24.93	3.47	31	25.48	1.57	25	24.96	2.65	0.42	0.66
False belief	11	7.91	0.30	27	7.89	0.32	21	7.57	0.68	3.12	0.05
Intention	11	4.00	0.00	27	3.93	0.39	23	3.91	0.29	0.31	0.74
Moral reasoning	11	8.00	0.00	25	7.88	0.33	20	7.90	0.31	0.68	0.51
Emotion reading	16	8.44	1.09	41	8.20	1.07	33	8.06	1.22	0.59	0.55
Cog. Empathy	16	9.06	3.38	34	8.47	3.35	29	8.52	3.77	0.17	0.84
Emo. Empathy	11	3.91	0.30	27	3.67	0.48	23	3.74	0.45	1.17	0.32
Desire	10	6.70	0.68	28	6.96	0.19	26	6.62	0.75	2.73	0.07
Motivation	10	6.70	0.68	28	6.96	0.19	26	6.65	0.69	2.54	0.09
Humour	17	4.88	0.33	38	4.50	0.65	31	4.03	0.95	7.99	0.001*
Proverb	18	8.94	0.80	39	8.51	1.14	29	8.45	1.27	1.20	0.31
Faux pas	11	56.18	3.84	32	58.97	2.71	28	58.68	2.41	4.251	0.02
Anger	12	1.33	1.37	25	1.80	1.5	25	1.56	1.33	0.48	0.62
Apathy	13	12.77	2.32	32	14.22	3.11	26	15.08	4.03	2.05	0.14
P. Attitudes	13	7.88	0.72	36	7.81	0.96	30	7.57	0.56	1.01	0.37

*Significant variance with Bonferroni correction formula for multiple comparisons; threshold (p = 0.003)

Table 2.8 Score range, means, and cut-off points within each age group

Measures	Age Groups												
	≤60					61-69				≥70			
	Scores range	n	Mean	SD	Cut-off scores	n	Mean	SD	Cut-off scores	n	Mean	SD	Cut-off scores
Go/No-go	0-27	14	24.93	3.47	19	31	25.48	1.57	23	25	24.96	2.65	21
False belief	0-8	11	7.91	0.30	7	27	7.89	0.32	7	21	7.57	0.68	6
Intention	0-4	11	4.00	0.00	4	27	3.93	0.39	3	23	3.91	0.29	3
Moral reasoning	0-8	11	8.00	0.00	8	25	7.88	0.33	7	20	7.9	0.31	7
Emotion reading	0-10	16	8.44	1.09	7	41	8.20	1.07	6	33	8.06	1.22	6
Cog. Empathy	0-14	16	8.20	3.38	3	34	8.47	3.35	3	29	8.52	3.76	2
Emo. Empathy	0-4	11	3.91	0.30	3	27	3.67	0.48	3	23	3.74	0.45	3
Desire	0-7	10	6.7	0.68	6	28	6.96	0.19	6	26	6.62	0.75	5
Motivation	0-7	10	6.7	0.68	6	28	6.96	0.19	6	26	6.5	0.69	5
Humour	0-5	17	4.88	0.33	4	38	4.50	0.65	3	31	4.03	0.95	2
Proverb	0-10	18	8.91	0.80	8	29	8.51	1.14	7	29	8.45	1.27	6
Faux pas	0-60	11	56.18	3.84	50	32	58.97	2.72	54	28	58.68	2.41	55
P. Attitudes -	0-10	13	3.58	0.76	<5	36	3.42	1.03	<5	30	3.23	0.94	<5
p. Attitudes +	0-10	13	8.52	0.86	>7	36	8.32	1.1	>7	30	8.44	0.93	>7
Anger †	0-24	12	1.33	1.37	4	25	1.8	1.5	4	25	1.56	1.33	4
Apathy †	0-36	13	12.77	2.32	17	32	14.22	3.11	19	29	15.08	4.03	22

† Deficits are determined by high means

2.3.4 Differences between Controls and Stroke Survivors

In general, the SCS succeeded in providing an informative and sensitive assessment across an array of social cognition tasks commonly affected by brain injuries and which have a direct impact on everyday social and psychological life. The comparison between healthy controls and stroke survivors of a particular age group revealed significant differences on all measures except three, which were marginally significant, falling above the Bonferroni corrected threshold for significance ($p < 0.003$). These measures were desire ($F(1,91) = 8.397$, $p = 0.005$), motivation ($F(1,91) = 8.491$, $p = 0.005$), and apathy ($F(1, 100) = 5.322$, $p = 0.023$). See **table 2.9** for more details on the comparisons of the performance of the control and patient groups on the SCS measures.

Unlike the relation of desire and intention as a goal ($r = 0.37$, $p = 0.05$), desire and motivation were highly associated ($r = 0.94$, $p = 0.0001$), and this is justified because desires are considered to be the goal for satisfying an impulse ‘motivation’ (Reiss, 2004), so motivation is a condition precedes desire, and desire satisfaction can lead to motivation satisfaction but the same cannot be said about the relation between desire and intention. For instance a sandwich can satisfy a hungry person, however, the plan for getting that sandwich (intention) may vary, and even after choosing a specific plan, the desire may not always be accomplished as planned but changing the desire can lead to the satisfaction of the motivation, such as he goes to the shop but they run out of sandwiches so he eats a chocolate bar instead.

While it can be argued that the non-significant differences between the groups on the aspects of social cognition (namely, desire, motivation and apathy) by sample size and choice of task, there is reason to believe that these aspects might be *immune* to the brain damage.

Table 2.9 Performance comparisons between the control and patient groups on the Social Cognition Screen measures

Measures	Controls			Patients			F	p
	N	Mean	SD	N	Mean	SD		
Impulsivity	70	25.21	2.296	27	22.74	5.059	11.488	0.001
False Belief	59	7.78	0.494	38	6.68	1.461	29.825	0.000
Intention	61	3.39	0.309	48	3.27	0.984	24.713	0.000
Moral reasoning	56	7.91	0.288	43	6.98	0.938	49.556	0.000
Emotions reading	90	8.19	1.131	46	6.48	1.859	44.33	0.000
Cog. empathy	78	9.10	3.086	31	6.52	2.897	16.122	0.000
Emo. empathy	61	3.74	0.444	42	3.19	0.74	21.947	0.000
Desire	62	6.84	0.486	31	6.19	1.621	8.397	0.005
Motivation	62	6.89	0.370	31	6.35	1.33	8.491	0.005
Humour	86	4.41	0.788	39	3.03	1.597	42.058	0.000
Proverbs	86	8.58	1.132	39	6.56	2.125	47.878	0.000
Faux pas	71	58.42	2.926	30	47.33	12.413	50.659	0.000
Anger	64	1.63	1.374	27	4.96	3.492	21.254	0.000
Apathy	71	14.27	3.414	31	16.16	4.612	5.322	0.023
Psy. attitudes	79	7.732	0.792	37	6.90	0.928	24.87	0.000

*Bonferroni correction for multiple comparisons; threshold (p=0.003).

In considering desire, for example, it is plausible to assume that this ability is less likely to be affected by brain damage as it emerges during the early phases of development. From about 18 months of age, children are able to recognise desires in others and are able to distinguish between what other people want or desire, and what they do not want. From this age, they also understand the link between desires and emotions, recognising that desired objects cause happiness, whereas undesired objects may cause disgust (Repacholi and Gopnik, 1997). Moreover, they develop the ability to reason about other people's desire before developing the ability to reason about others' beliefs (Shahaeian, Peterson, Slaughter, & Wellman, 2011). Consequently, the function of understanding the other's desire might operate in a more distributed network of brain regions, and thus, when a specific area is damaged, the mechanism subtending desire can continue to operate, albeit in a compensatory manner, perhaps.

The lack of significance on the apathy scale can be interpreted due to the inherent bias within the control and patient samples. Since the main drive of apathy is lack of motivation and withdrawal from social activities, whereas higher level of motivation is considered the main trait of the volunteers characteristics; they tend to maintain higher levels of motivation and control on different aspects of their lives (Miller, 1985; Mirheidari, Ghiami-Rad & Rostamifard-Ahari, 2011) and they expect that volunteering would satisfy their growth needs (Miller, 1985). The results of assessing apathy may change when this scale performance merges with other measures within a factor domain and also when assessing patients randomly following brain injuries in hospitals. It would be interesting to explore these relationships with item reduction methods such as factor analysis in order to explore the underlying common features of aspects of social cognition.

CHAPTER 3

THE DOMAIN STRUCTURE OF POST-STROKE DEFICITS IN SOCIAL COGNITION

Synopsis

In Chapter 2, I described the construction and validation of a new battery for the assessment of social cognition following brain injury. Recent evidence from brain functional studies has supported the notion of a modular structure underlying ToM abilities, with separate component parts involved in specific, differing mentalizing processes (Abu-Akel, 2003; Bodden et al., 2010; Shamay-Tsoory & Aharon-Peretz, 2007), and empathy (Eres, Decety, Louis & Molenberghs, 2015; Harari et al., 2010). These issues can be addressed through a large-scale clinical study that assesses the associations and dissociations between tests. Here I analyse social cognitive performance of a group of stroke survivors in terms of its latent factors, as revealed through Factor Analysis. This is in order to evaluate the potential contribution of clusters of variables (or factors) to impairments in social cognition in this sample, and analyse the relationship of these factors to cognitive dysfunction and brain lesioned areas.

3.1 INTRODUCTION

As described in the previous chapters, social cognition broadly refers to the outcome of cognitive processes and structures that enable people to form perceptions about ‘themselves’ in relation to other people, and to analyse psychosocial phenomena. It involves the impact of our perception on the way we think, feel and respond to others in social environment, and to what extent we correspond to the opinion of others to change the way we think, feel, and respond to the world.

Stroke survivors and their family often report problems social interaction, personality, emotions and social behaviour. In many cases, the problems in social cognition are major determiners of successful outcomes (Andersson, Gunderson & Finset; 1999; Fett et al, 2011; Shimoda & Robison, 1998; Venna, Xu, Doran, Patrizz & McCullough, 2014), rather than domain general abilities (see: Fett et al, 2011, in a quantitative meta-analysis study).

Social cognition elements are mostly multidimensional constructs (e.g. ToM, empathy, and apathy) and relatively little is known about the relationships among more specific aspects of each. It is also unclear which aspects are most affected and which are immune to brain damage, and more specifically what aspects are most likely to be affected due to a deficit in another. These issues can be addressed through a large-scale clinical study that assesses the degraded functions common after stroke in addition to help understanding the factorial structures underlying social cognition and the components utilised under each factor.

There have been several recent attempts to explore underlying latent factors compromised by brain damage by using forms of factor analysis to extract common components behind test performance. An example has recently been reported by

Corbetta et al. (2015). After screening a relatively large number of patients 1-2 weeks post-stroke, Corbetta et al. entered 67 individuals into a principal components analysis using data from a set of cognitive tests of attention, language, memory and motor function. The results highlighted three factors reflecting (i) language and memory (including both verbal and spatial memory), (ii) indices of right hemisphere damage (left motor impairment, bias against the left field, general performance and spatial memory) and (iii) indices of left hemisphere damage (right motor impairment, bias against the right field and poor attention shifting). Corbetta et al. proposed that behavioural variations after stroke could be accounted for by a small number of anatomically-grounded factors that would not necessarily reflect classic neuropsychological syndromes (e.g., distinguishing between language comprehension and production).

In contrast to this, in an analysis focusing on language functions in left hemisphere stroke patients, Butler, Lambon Ralph and Woollams (2014) reported three underlying factors that are linked to phonology, semantics and executive cognition. Furthermore, these distinct factors were associated with brain lesions to different sites. Phonology was uniquely associated with lesions in central perisylvian areas including mid to superior posterior temporal gyrus, middle temporal gyrus, superior temporal sulcus and Heschl's gyrus. The semantic factor was linked to left anterior middle temporal gyrus, and the underlying temporal stem. The third factor, 'executive' cognition, which explained the least variance, did not relate to any brain regions.

In the area of visual attention, Verdon et al. (2010) analysed the latent factors underlying performance on a range of clinical tests of spatial attention (e.g., cancellation, line bisection) and reported a distinction between deficits on tests requiring scanning of

egocentric space and those requiring attention to the spatial positions of features in objects (egocentric and allocentric neglect as posited by Chechlacz, Rotshtein, & Humphreys, 2012). Again they linked these separate components to different brain lesions; the ‘perceptive/visuo-spatial’ factor to the right inferior parietal lobule, the ‘exploratory/visuo-motor’ factor with the right dorsolateral prefrontal cortex, and the allocentric/object-centred’ factor to the deep temporal lobe regions.

In the field of social cognition, this approach has been less evident and the vast majority of studies examined performance at the level of individual tests. Nevertheless, there are some indications from work within clinical population. For example, in relation to schizophrenia, Mancuso et al. (2011) used factor analysis to extract latent components across five tests of social cognition (covering emotional processing, social perception, attributional style, and Theory of Mind). They proposed that performance was dependent on three underlying factors: (1) hostile attributional style, (2) poor detection of low-level social cues (e.g. for facial emotion identification and lie detection), and (3) impaired inferential and regulatory processes (e.g. detecting sarcasm and managing emotions). Interestingly, factor 2 (poor detection of low-level social cues) accounted for variance in functional outcome over and above measures of neuro-cognition, suggesting a distinct contribution of this factor to everyday functioning. In contrast, Bell et al. (2009) argued for a four-factor model involving (i) affect recognition, (ii) Theory of Mind, (iii) egocentricity, and (iv) rapport. However, it is an open question as to how well these analyses apply to patients with organic brain lesions rather than to schizophrenia. It appears that the exact relationship between aspects of social cognition following stroke has yet to be elucidated.

Here, I used a statistical data reduction method the ‘Factor Analysis’ on the performance of the group of stroke survivors reported in chapter 2, to evaluate

potential latent variables contributing to impairments in social cognition in this population. In addition, the differences on factors performance between controls and patients will be carried out. This analysis would reveal which factors were affected (or not) post stroke.

3.2 METHODS

3.2.1 Factor Analysis

Participants

All of the tests in this work have been conducted on two samples; healthy controls and brain-lesioned patients. Participant of both groups were white English speakers.

Patients' sample

In first expletory analysis the patients' sample consisted of 49 patients [36 (73%) males and 13 (27%) females], with age ranging from 31-91 years old (Mean=65.66, SD=13.50), and years of education with an average of (Mean=11.87, SD=3.6).

All the patient were volunteers at a chronic stage of recovery from stroke (>9months post stroke) with time average (Mean=13.44, SD=3.55) months, signed a consent form, and were members of the patient panel at the Cognitive Neuropsychology Centre (CNC), University of Oxford.

Materials

Participants were assessed using a novel battery of tests, The Social Cognition Screen (SCS), which was designed as a part of my Doctoral research with the aim of developing a screen to detect socio-cognitive deficits after brain injury. The SCS consists of 15 tests designed and adapted to be aphasia-friendly and commensurate

with the common difficulties experienced after stroke. More details and description of the tasks are presented in **chapter 2**.

The tasks were examined with several methods in order to gain their psychometric features. Internal consistency for the patient sample showed an acceptable coefficient ($\alpha = 0.7$). Stability over time was assessed using a test-retest procedure with the patients, with the duration between the test and the retest ranging from 4 to 16 weeks. All the test retest values were correlated significantly at level ($p < 0.01$), more information provided at **chapter 2, table 2.3**.

The validity of the measures was assessed in comparison with external tasks and tests of specific social cognition function published in the literature, except for motivation and attitudes as they were novel tasks and provided with a control version. All correlation coefficients between the test in the SCS and measures of particular functions in literature were significant at $p < 0.01$. More information provided at **chapter 2, table 2.4**.

Procedures

Stroke patients, who were recruited by the CNC, Oxford University, were assessed on the SCS. However, at the time of conducting the factor analysis study, only 23 of the patients managed to complete the assessment on all the measures. Due to the lack of previous analysis particularly on stroke survivors' sample, confirmatory factor analysis for the study is not possible (Nesselroade & Cattle, 1988). In order to extract the underlying factors that best explains the patients' social cognition deficits, exploratory factor analysis followed by a varimax rotation to maximize orthogonality and Kaiser normalization that extracts factors with an eigenvalue ≥ 1.0 has been conducted. Due to missing data on some measures for the patients' sample, some of

data were excluded from the component analysis and therefore, the models produced were not reliable ($KMO \leq 0.05$, and non-significant results of Bartlett Test).

Generally, the results of factor analysis indicate an interaction between sample size and the number of variables, as the probability of error tends to be minimized and the accuracy of population estimates is maximized which will support the generalizability of the results (Osborne & Costello, 2004). Therefore, the models produced initially have not obtained the required specification. In order to find a more adequate model, I maximised the patients sample size by adding a homogeneous age and education background group of healthy controls to the analysis. **Table 3.1** contains the final demographic data of the sample. Further statistical analysis addressed the variances of factor performances between healthy controls and patients to identify *immune* and *fragile* factors of social cognition. Also, the possible relationships between produced factors were explored.

Table 3.1 Demographics of the sample of study

Demographics	Patients (N=23)	Controls (N=16)
Gender (M/F)	(16/7)	(10/6)
Age	63.48±13.76	65.4±8.38
Education	11.87±3.6	12.46±3.6
Primary & Secondary School	10	6
College & Non-University Diploma	6	4
University degree	7	6

3.2.2 Comparisons between the Mean Performances of Controls and Patients

Participants

The patient group consisted of 26 participants (19 males and 7 females) with a mean age of 63.39 (SD=12.92). The healthy controls consisted of 26 participants (13

males and 13 females) with a mean age 65.89 (SD=8.42). A t-test showed no differences between the groups in age [$t(49.5)=0.41$, $p=0.05$], or in the distribution of gender.

Procedures

In order to compare between patients and healthy controls, their raw scores on each SCS factor were converted into Z-scores, using the controls group mean and standard deviation across each factor. The calculation of the Z-scores were performed using the following standard formula

$$Z = \frac{(x - \mu)}{\sigma}$$

where (x) was the raw score of performance, (μ) was the mean of controls in that assessment and (σ) was the standard deviation of the controls' performance for the assessment.

3.3 RESULTS AND DISCUSSION

In order to check the homogeneity of the controls sample added to the stroke survivors, an independent samples t-test comparing the mean age of the patient and control groups were conducted. The results revealed no significant difference ($t(40)=0.581$, $p=0.564$). There was also no significant difference between the patient and control groups in years of education ($t(40)=0.512$, $p=0.692$).

Taking the data for the patients and controls together, the Anti Correlation Matrix (ACM) coefficient cut-offs were moderate and ranged between $r = 0.54$ and $r = 0.93$. The results of the KMO measure of sampling adequacy showed a moderate patterned

relationship (KMO= 0.70), with significant Bartlett Test of Sphericity (BTS= 0.34, $p<0.001$) which confirms the existing of patterned relationships—the variables were considered to be part of the factor if their factor loading was greater than 0.60. The model indicated four factors that explained the majority of the total variance (70%). The number of the significant factors, factor-loading measures, eigenvalues and the variances explained are reported in **Table 3.2**.

3.3.1 The Domain Structure of Social Cognition Deficits in Chronic Stroke Survivors

Factor 1 represents '*Social Cognition Control*' (SCC) and explained the largest proportion of the behavioural variance representing 29.82%, or one third of the total variance. Eight measures were integrated in this factor and included proverb, humour, false belief, anger, impulsivity, emotional reading, faux pas and moral reasoning. The main feature shared by these measures, is that they represent socio-cognition abilities that, as one would expect, often become impaired in post-stroke patients. Interestingly, these social cognition abilities loaded along with impulsivity (the Go/No-Go task an inhibition control task), which suggest that deficits in social cognition in stroke patients may be aggravated by cognitive impairments. As such, this factor may reflect the contribution of executive load on performance (Fino et al., 2014).

Table 3.2 The factor loadings, measures, eigenvalues and the amount of variance accounted for.

Measures	Factor 1	Factor 2	Factor 3	Factor 4
	SCC	Motivation	IO	Mindreading
Proverb	0.850	0.058	0.284	0.112
Humor	0.841	-0.096	-0.183	0.206
False belief	0.770	0.314	0.144	-0.095
Anger	-0.744 †	-0.364	-0.113	-0.073
Impulsivity	-0.699 †	0.067	0.032	0.116
Emotion reading	0.654	0.258	0.214	0.201
Faux pas	0.620	0.456	0.032	-0.111
Moral reasoning	0.611	0.332	0.383	0.227
Desire	0.248	0.917	0.109	0.161
Motivation	0.206	0.883	-0.040	0.173
Cognitive Empathy	-0.005	0.079	0.717	0.347
Psy. attitudes	0.140	0.263	0.700	-0.253
Apathy	-0.190	0.253	-0.684 †	-0.223
Emotion empathy	0.116	0.077	0.084	0.868
Intention	0.228	0.358	0.235	0.630
Eigen values	4.474	2.548	1.902	1.627
Variance explained %	29.824	16.985	12.681	10.845
Cumulative variance	29.824	46.809	59.490	70.334

SCC =Social Cognition Control. IO= Interest in Others.

† Higher means in these measures indicate greater deficits

The relationship between ToM and Executive Functions (EF) has frequently been discussed in the literature (e.g., Aboulafia-Brakha et al., 2011, Saxe et al., 2006; Sabbagh, Xu, Carlson, Moses & Lee 2006), to determine whether ToM is a domain specific ability or rather part of a domain general function, and specifically, whether EF is necessary precisely for developing and acquisition of ToM, or for the execution of ToM as well. Indeed, it has been shown that degraded EF performance tend to associate with deficits in ToM (Aboulafia-Brakha et al, 2011), humour (Uekermann et al., 2008), identifying emotions and faux pas (Ahmad & Miller, 2011), and anger (Denny, 2014). Although there some evidence from a case study of a patient with

amygdala damage who failed ToM but his EF abilities found to be intact (Fine, Lumsden & Blaire, 2001). Furthermore, Havet-Thomassin et al. (2006) tested this association in a group of patients with frontal lobe brain injuries, using the ‘Stroop’ and ‘Trail making’ tasks as indicator to the EF and the ‘RMET’ for ToM. Their results indicated no causal effect and the performance on EF tasks did not predict the RMET. This relationship could reflect selective problem related to inhibition control.

Overall, the current study results is in favour of the necessity of inhibition control ability, a specific element of the EFs, in accomplishing ToM and other related social cognition abilities, which might be instrumental to supressing self-beliefs and distinguish between self and others thoughts and beliefs. This would be in line with Saxe, Schulz, and Jiang (2006) that suggested the involvement of both domain-general and domain-specific cognitive resources in adult ToM. However, hence, six other measures loaded in this factor, this result might apply to the rest of the measures loaded in this factor including proverbs, humour, emotion recognition, anger, moral reasoning and faux pas, it would be interesting to investigate the relations of the SCS measures with other elements of EF such as working memory, controlled and sustained attention, so as to identify the domain general particularly needed for specific aspect of social cognition.

Factor 2 was labelled as ‘*Motivation*’ and included two highly correlated measures accounting for 16.99% of the total variance – understanding motivation and desire. The tasks are designed to assess visual prospective taking, which is perceived as a low-level mechanism (Apperly & Buttwefill, 2009). The motivation and desire tasks both require the processing and understanding of motivational drivers of behaviour. Here, the coupling across both tasks indicates that an underlying motivation-related factor may be selectively affected by brain lesion. Faux pas shared

cross-loadings with this factor (0.456) and the SCC factor (factor 1)– perhaps because it requires not only executive control of attention but also the ability to apply social rules based on understanding the motivations behind the social behaviour. Interestingly, desire overlapped with motivation rather than intention, which may suggest that identifying others desire is linked to the drive underlying the goal directed behaviour rather than the strategy undertaken to satisfy that desire which may not be consistent with the desire.

Factor 3, labelled '*Interest in Others*' (IO) accounted for 12.68% of the variance. This factor loaded on three measures: cognitive empathy, apathy and psychological attitudes. The variables in this dual dimension factor are characterised with the social tendency to interact with others. The psychological attitudes task required making assumptions about a stable set of representations of others' based on their preference for the stimulus and deciding whether they are in favour or disfavour of the attribution subject (Cunningham, Zelazo, Packer, & Van Bavel, 2009). Positive psychological attitudes and higher degree of cognitive empathy correspond to lower level of apathy (Eslinger et al., 2012). They represent the positive tendency of this domain and reflect the openness to share experiences and interests with others, care to engage in social interactions including the consideration of others thoughts, feelings, and reactions in social contexts. On the other hand, negative psychological attitudes and lower degree of cognitive empathy correspond to higher level of apathy, which is characterized by lack of motivation, social withdrawal and refraining from new experience. The apathy task estimates the individuals' motivation and tendency towards socialisation. A lack of interest in others could contribute to poor understanding of psychological attitudes and to apathy. It is interesting that apathy loaded on this factor and on the factor

linking desire and motivation reasoning. Apparently understanding motivation in others (factor 2) may be distinct from being motivated (factor 3).

The final factor, factor 4, labelled '*Mindreading*', loaded on two measures—understanding others intention and emotional empathy—and accounted for 10.85% of the total variance. The variables in this factor are characterised by the ability to speculate others intentions by analysing the facts of the social context and the associated mental states believed to symbolise the observed action. Both variables may involve selective processes implicated in forming predictions about how others may feel in given context. Evidence from previous studies supported the association between these variables as they were found to rely on the activation of similar brain networks involved in social perception, namely the mPFC, superior temporal lobe and temporal pole, whilst emotion identification required the additional engagement of the amygdala as a part of emotional networks (Völlm, et al., 2005).

Taken together, the data suggest that there are commonalities across a range of social cognition tests, rather than different tests isolating particular social component processes. The results pertaining to the relationships between the variables in each factor were consistent with the results of previous studies. For example, false belief and desire loaded onto two separate factors, namely the SCC factor and the motivation factor, respectively. This separation is consistent with findings in the literature (Bodden et al., 2010; Kalbe et al. 2010; Shamay-Tsoory & Aharon-Peretz, 2007) ascribing these abilities to distinct neural circuits. Interestingly, Decety and Cowell (2015) findings support the distinction between moral reasoning, which loaded onto the social cognition control factor (factor 1), and empathy, which loaded onto the mindreading factor (factor 4). Decety and Cowell (2015) examined the multiple physiological, hormonal, and neural systems supporting empathy and its

functions, in relation to justice and moral behaviour. They found that empathy produces social preferences that can conflict with fairness and justice.

The model presented for social cognition factors revealed associations the SCC factor (factor 1) with a measure tapping inhibitory control (Go/ No-go task), which is an essential element of EF that enables the suppression of actions and reluctance to irrelevant stimuli involvement (Friedman & Miyake, 2004). This association perhaps highlights the effortful demands required for processing overlapped measures in this domain. In general, EF underscore accomplishing the tasks as it concerns the engagement of goal directed behaviour as well as modifying behaviours based on situational demands (Williams, Suchy & Rau, 2009). The remaining measures appear to represent social domains less dependent on inhibitory control and may rely on other cognitive domains, or alternatively, involved tasks that succeeded to control for the inhibitory demands for the task. For instance, the motivation, desire, intention, and emotion empathy procedures required the participant to state their own view before asking them to consider others' minds and actions. This assumption can be investigated in more extensive study which includes a range of cognitive abilities such as attention, working memory, language, problem solving, and analysed with social cognition aspects to understand to what extent social cognition elements are reliant on other higher cognition capabilities in order to operate normally.

Alternatively, if social cognition elements loaded independently on a factor, this may mean that the social factor is supported largely by a domain specific operation rather than being a part of a domain general operation, and may even constitute a distinct ability. Some social cognition factors are expected to load specifically with other social cognitive components for other reasons.

3.3.2 Comparisons between the Mean Performances of Controls and Patients

An analysis of variance (ANOVA) was conducted to investigate the significant variances between the assessment of control and patient groups. After Bonferroni correction for multiple comparisons, differences between the groups were considered significant at $p \leq 0.012$. The results revealed significant differences between the groups on three factors, where patients performed significantly worse than controls. Differences were observed in Social Cognition Control [$F(1,50)=32.00$, $p < 0.001$], Interest in Others [$F(1,50)=26.11$, $p < 0.001$] and mindreading [$F(1,50)=24.72$, $p < 0.001$]. However, the difference between the groups on motivation factor was not significant [$F(1,50)=4.529$, $p=0.038$], although the difference was in the direction expected. For more details on ANOVA analysis between groups see **Table 3.3**

Table 3.3 Comparison between controls and patients factors

Factors	Controls		Patients		F	P
	Mean	SD	Mean	SD		
Social cognitive control	0.482	0.162	2.237	1.573	31.995	0.000
Motivation	0.494	0.491	1.343	1.976	4.529	0.038†
Interest in Others	0.493	0.171	1.069	0.549	26.11	0.000
Mindreading	0.357	0.154	1.497	1.159	24.724	0.000

† Bonferroni correction for multiple comparisons; threshold ($p < 0.012$)

The findings of this investigation showed significant differences between controls and patients performances on three factors; social cognition control, interest in others and mindreading. The significant differences between patients and controls on the factors produced by the previous model confirm that stimuli used to assess each component were sensitive to detecting the defected performance, although the patients were volunteers and have passed the acute cognitive disruption following stroke.

However, the selective ‘motivation’ attribution deficit as low-level mechanism suggests that understanding of others’ desires and motivations alone will not be sufficient to function properly in a complex social situation. As an internalised early developing ability, desire attribution may be processed in multiple brain regions and this may be the reason that this factor was preserved, or least affected, comparing to other factors. Perhaps, as an independent domain more resistance to the brain damage following stroke, motivation and desire attribution could be a potential strength that can be called upon during rehabilitation.

Furthermore, in order to explore the relationship between the social cognition factors, correlation between the scores of four factors was conducted. The results revealed significant relations only between the social cognition control and the motivation factors ($r=0.49$, $p=0.05$), which raises the question as to whether deficits on social cognition control factor can predict deficits in motivation. To address this question, a multiple regression has been conducted where the z- standardised scores of social cognition control factor was set as predictor and the raw scores of motivation factor as the dependant factor. The analysis revealed a significant model, [$F(1,24)=7.602$, $p<0.011$], $R^2=0.241$, explaining 24% of the variance, where the social cognition control factor was positively associated with the motivation factor ($\beta(se)=0.616 (0.233)$, $t=2.757$, $p=0.011$). Whilst the dissociation between SCC, IO and mindreading factors may highlight the differences between social cognition factors even within the same theoretical domain, for instance attributing others belief and intention have been used interchangeably under the ToM concept and as a cognitive domain by researchers, and this holistic view may not be adequate. Our result based on the analysis of latent characteristics of a set of variables illustrate a more specific trend of relationships that may differ within the same theoretical domain, for instance the dissociation between

reading emotions (in SCC factor), desire attribution (in motivation factor) and emotional empathy (in mindreading factor), although all may reflect affective aspects of social cognition. This may be explained partly due to neuro-circuits supporting each factor and can be investigated with quantitative analysis of the lesion, however, there might be other reasons involved such as selectivity. For example patients who assessed as intact SCC might be able identify others emotional states but may choose not to involve themselves with others' emotional states (emotional empathy), and as Decety and Cowell (2015) suggested empathetic social preferences can conflict with social norms of morality and justice.

To sum up, three of the social cognition factors; social cognition control, interest in others and mindreading are factors that may be operating independently, and possibly supported by distinct mechanisms. However, the motivation factor appears to be dependent on social cognition control. This assumption finds support in the observation that all the patients with defected performance on motivation factor were also impaired on social cognition control factor, but not the reverse. More broadly, the findings of the present study may have implications concerning research practices investigating social cognition and its correlates. When investigating the relationship between social cognition and higher cognitive domains, many studies tend to use a broad range of tasks, such as ToM, to index social cognition, and EF tasks such as the Stroop task to index higher cognitions, rendering the generalisability of such findings limited. Evidence from the factor analysis in this study revealed distinctions between variables used repeatedly and interchangeably in the literature, such as FB and intention. Furthermore, the limitation also applies to EFs. For instance, the 'Stroop task' assesses a specific form of inhibition (interference control). Therefore, it is not accurate to use it as an indicator for the wide variety of cognitive processes involved in EF.

3.3.3 Limitations

The results of this chapter need to be considered with respect to a number of limitations. First, the study's sample is relatively small. This may have affected the results of the current exploratory factor analysis, given that explanatory factor analyses are known to work better with larger sample sizes (Yong & Pearce, 2013). Therefore, a replication with a larger sample size is necessary, and thus factors need to be interpreted with caution. Moreover, the current results should be interpreted with caution due to the large number of variables. However, given the wide array of cognitive and socio-cognitive functions observed in stroke patients, clinical screens need to include a wide range of tests to minimize misdiagnoses and incomplete profiling of patients' abilities.

3.3.4 Conclusions

In conclusion, the results lend support to the possibility that social cognition abilities may be distinguishable and can be classified into four underlying processes: (1) complex aspects that require domain general abilities (e.g. inhibition control) as to operate normally, and include cognitive, affective and social knowledge variables. Deficits on this factor can be linked to domain general deficits; (2) aspects that require automatic analysis of affective phenomena, depending on responses and consequences of observed behaviour. Deficits on this factor may reflect misunderstanding others' motivations and desires; (3) aspects concerning social engagement, which when impaired, may lead to social withdrawal as well as deficits in reproduction of the previously learned behaviour in seemingly appropriate contexts; lastly, (4) uncomplicated mindreading aspects that can operate independently and act upon selective willingness to think about others' cognitive and affective mental states. Individuals with impairments on this factor might be characterised by self-bias and

egocentric interpretations to the psychosocial phenomenon. Moreover, notwithstanding the study's limitations, the current results are encouraging for further research concerned with the relations between these social cognition components and different aspects of EF, such as rule finding and working memory, along with other cognition domains linked to social cognition, and will provide insight into the functions underlying aspects of social cognition. Moreover, the factor analysis may help in highlighting most pertinent test domains for stroke patients.

CHAPTER 4

THE COGNITIVE IMPLICATIONS FOR SOCIAL COGNITION DEFICITS AFTER STROKE

Synopsis

In the previous chapter, a factor analysis was applied to data collected from post stroke patients who completed the Social Cognition Screen (SCS), revealing four factors. The primary factor was ‘social cognition control’, which explained the largest proportion of behavioural variance. This to be expected given the fact that, clinically, post stroke socio-cognition deficits tends to be dominated by cognitive impairments. However, this factor consisted of several social cognition competences that were associated with inhibitory control, which is related to Executive Functions (EF). This finding raised several queries about the relations between the social components combined in this screen and other domain general capabilities including different aspects of the EF such as planning and working memory.

In this chapter, I aim to advance our understanding of the cognitive processes that can affect the functioning of social cognition. Here I employ the Birmingham Cognitive Screen BCoS (Humphreys, Bickerton, Samson & Riddoch, 2012)—and extended battery of cognitive measures—in order to identify and explain the underlying cognitive domains that can contribute to the deficits of social cognition functions, as well as to detecting possible cognitive predictors.

4.1 INTRODUCTION

As it has been reviewed, the term ‘social cognition’ embodies a multitude of cognitive structures and processes that influence social interactive mutuality between the individual and other people in social contexts. This includes, but not limited to, both the recognition and the implementation of social knowledge, moral norms, rules, emotions recognition and attribution. Social cognition studies have largely relied on ToM assessment as a key indicator of social competences, regardless of the viability of this assumption (Apperly, 2011). These studies often linked ToM with one or more elements of EFs, both during its development and acquisition (Miller & Marcovitch, 2012; Sabbagh et al., 2006) as well as during production and execution of ToM processes (Henry et al., 2006; Samson, Houthuys & Humphreys, 2015; Saxe et al., 2006). EFs refers to a set of functions involved in planning, set shifting, working memory, attention (Ball, Holland, Watson & Huppert, 2010; Lin, Keysar & Epley, 2010), inhibitory control (Turner & Spring, 2012), self-regulation (Hofmann, Schmeichel & Baddeley, 2012), as well as the organization, management and execution of goal directed behaviours, especially those which involve novel and complex situations and which require creativity and the interaction between different cognitive processes (Gilbert & Burgess, 2008; Verdejo-García & Bechara, 2010, Cardoso et al., 2015). In addition, social cognition has been linked to higher cognitive demands such as intelligence, memory and language (Malle, 2002; Sellabona, 2013). For instance, in a quantitative meta-analysis investigation, significant association has been revealed between general intelligence and the reading the mind in the eyes (RMET) (Baker, Peterson, Pulos & Kirkland, 2014).

Yet, investigations of the association between EFs and social cognition revealed inconsistent findings. For instance, Van Overwalle (2009) undertook a meta-analysis

to explore what areas of the brain are involved in social cognition, and with regard to people's behavioural intentions, social beliefs, and personality traits. The results of over 200 fMRI studies suggest that the temporo-parietal junction (TPJ) is the brain area that impacts how goals, intentions, and desires of other people are interpreted in the short term, and represented at more concrete level, while the medial prefrontal cortex (mPFC) was found to be more involved in determining more long-lasting impressions of others and the self and represented at more abstract level. Other tasks reflecting general-purpose brain processes that may potentially be involved with social cognition such as sequence learning, causality detection, emotion processing, and executive functioning were also examined but they did not appear to overlap with the brain areas that were activated during social cognition.

Interestingly, evidence from 'inhibition control' (Turner & Spring, 2012) found to be crucial for solving cognitive (e.g. attention and working memory) and social cognition aspects' tasks including attributing others' emotion, desire, belief and visual experiences, precisely when these experiences conflicted with the participant's own experiences (Samson, Apperly, Kathirgamanathan & Humphreys, 2005; Stone, 2005). As far as EF role in suppressing self-prospective is concerned, some studies suggested a pivotal role in processing belief and desire attribution. In their study, Apperly, Samson and Humphreys (2005) assessed a patient with a right fronto-temporal lesion on a series of cognitive and socio-cognitive tasks. The patient performed more accurately on a reality-unknown belief condition task compared to reality-known false belief condition, in addition to degraded execution on tasks requiring the attribution of others' desire, visual and emotional perspective as well as impaired performance on a set of social and non-social tasks demanding inhibitory control. Taken together, the

authors attributed the impaired pattern of performance to defective self-perspectives inhibition.

However, there is converging evidence that self-prospective inhibition requires executive control. In a recent study, Samson, Houthuys and Humphreys (2015) investigated the link between self-prospective inhibition and more executive control abilities, by comparing the performance of two pairs of brain-lesioned patients. The first pair consisted of two patients with similar brain damaged areas; one of them had previously been known (from past case studies) to suffer from deficits in self-prospective inhibition. The second pair showed similar executive control deficits in classic neuropsychological tests as the first pair but, with different brain lesions' location. For the first pair (i.e., the patients with selective deficit in self-prospective inhibition, the results revealed that they do not necessarily have impaired resisting interference from distracting information other than their own prospective when mentallizing. The second pair (i.e., those patients with severe executive control impairments) does not appear to have difficulties in inhibiting their own prospective when mentallizing. The authors concluded that self-prospective inhibition is a selective deficit that cannot be explained by general executive control difficulties.

Messa, Wang, Bickerton, Demeyere, Riddoch, and Humphreys (2015) found that post-stroke domain-specific deficits could only be understood in relation to linked changes in domain-general processes. They used the Birmingham Cognitive Screen (BCoS) (Humphreys, Bickerton, Samson & Riddoch, 2012). An assessment of 287 patients was conducted to determine how neuropsychological deficits can be detected using a broad, time-efficient screen that can assess both 'domain specific' and 'domain general' cognitive deficits and to generate a specific cognitive profile for individual patients. Their results were presented by means of graphical modelling

techniques to investigate the associations and interdependence between deficits within and across the domains of the BCoS tests. On an individual basis, there was no significant difference compared to the results from existing cognitive models. However, when the whole dataset was modelled, significant differences were found, indicating that domain-specific deficits are better understood when linked to domain-general processes, which would help to evaluate neuropsychological deficits after stroke.

Using factor analysis method to extract common components behind test performance and to explore the underlying concealed factors compromised by brain damage is an effective method used for understanding social cognition dysfunction. Fett et al. (2011) investigated the relationships between neurocognitive and social cognitive functioning and different types of functional outcome in a meta-analysis covering 52 studies of patients with schizophrenia. The findings revealed four factors, and stronger associations have been found between ToM and functional outcomes rather than all the neurocognitive domains (except verbal fluency), and that emotional processing was more strongly associated with community function than attention and vigilance. It would be interesting to explore the relationships of deficits in a stroke sample.

While previous chapter has provided some insight about the relationship between cognitive and socio-cognitive abilities, our understanding the relationship between these two broad multidimensional constructs remains limited. To shed further light on this line of inquiry, in this chapter I investigate which cognitive domains (including inhibition control, language, EF and episodic memory) influence the social cognition aspects included in the SCS? Which aspect of the EF deficits can best predict difficulties in belief attribution, and other aspects of the SCC? The identification of

specific relationships between EFs and social cognition operations, could lead to the identification of targets for treatment in rehabilitation plans.

Therefore, the first goal of the current study was to determine the underlying factors that stand out the relationships between measures of social cognition and general cognitive domains through factor analysis in stroke survivors' sample and reveal the cognitive aspects that mostly influence social cognitions functions. The second goal was to identify the general cognitive aspects that best predict impaired social cognition function. As was mention in chapter three, SCC factor composed of seven variables that associated with a go no go task that tap into general ability (inhibitory control), I hypothesised that some variables of SCC factor would associate with general cognitive domains.

4.2 METHODS

Participants

The neuropsychology sample consisted of 25 patients volunteers [18 (72%) males and 7 (28%) females] with heterogeneous lesions due to the stroke. Participants' age ranged from 31-86 years old ($M = 63.56$; $SD = 11.68$), and they received an average of years of education ($M = 12.04$; $SD = 3.47$). All the patients were white English speakers at a chronic stage of recovery from stroke (>9months post stroke). Participants gave informed consent in agreement with an ethics protocol approved by the U.K. National Research Ethics Committee, and were members of the patient panel at the Cognitive Neuropsychology Centre (CNC), Department of the Experimental Psychology-University of Oxford.

a. The Social Cognition Screen (SCS):

Participants were assessed using two test batteries. First is a novel battery of tests, the Social Cognition Screen (SCS), which was designed as a part of my Doctoral research with the aim of developing a screen to detect socio-cognitive deficits after brain injury. The SCS encompasses 15 sub-scales/tasks that assess four domains of social cognition and which include (1) social cognition control, (2) motivation, (3) interest in others and (4) mindreading. The tasks were examined with several methods in order to ascertain their psychometric features. Internal consistency for the patient sample showed an acceptable coefficient ($\alpha = 0.7$). Stability over time was assessed using a test-retest procedure with the patients, with the duration between the test and the retest ranging from 4 to 22 weeks. All the test retest values were not significantly different from each other (see Chapter 2, Table 2.3). The validity of the measures was assessed in comparison with external tasks and tests of specific social cognition function published in the literature, except for motivation and attitudes, which were novel tasks with corresponding control versions. As shown in Chapter 2, patients' performance on the SCS and the validation tasks correlated significantly ($p < 0.01$) (see Chapter 2, Table 2.4).

b. The Birmingham Cognitive Screen (BCoS):

BCoS is an instrument designed to provide a sensitive, time-efficient, inclusive and informative analysis of the cognitive profile of stroke patients across a range of clinically important abilities namely: attention and executive function, language, memory, number skills and praxis and action. It can be administered in a single one-hour testing session. It is also designed to minimize problems of neglect, aphasia and hemiplegia, which could influence the results of the BCoS. The BCoS is underpinned

by four philosophies, namely to use short, high-frequency words, use vertical layouts and multi-modal presentations (for neglect), use tests that are sensitive (will detect a problem if one is present) and indicate general domain deficits (e.g., problem in naming, but not exact problem) and design tests to incorporate several measures (to maximise time efficiency). This provides information about co-occurring deficits, which, due to their combined action, can affect social cognition to a greater or lesser extent. The cognitive profile also enables assessors to control for effects of co-occurring deficits when analysing data. In addition, the BCoS provides measures of several executive functions (controlled, selective and sustained attention, working memory, rule finding and concept switching) not covered in many tests.

The BCoS is comprised of 28 measures to assess domain specific abilities underlying each primary domain. However, only the scores of ten measures were chosen for this analysis. These measures fall into 4 domains and include: picture naming (language), immediate recognition, delayed recognition and story decay (memory), rule-finding including accuracy and rule (EF), spatial attention (EF) and controlled attention (EF/working memory) and finally figure copy and multi-step object use (planning/ praxis). The number domain was found to be closely related to the language domain (Messa et al., 2015), and so it was omitted here to reduce the number of tests included in the analysis.

Procedures

a. Sandside scores preparation

Patients' raw scores on the SCS measures and the BCoS were converted into Z-scores, using the patient's group mean and standard deviation across each measure, using the following standard formula:

$$Z = \frac{(x - \mu)}{\sigma}$$

where (x) was the raw score of the patient performance, (μ) was the mean of the patients performance in that assessment and (σ) was the standard deviation of the patients' performance for the assessment.

b. Factor Analysis

An exploratory factor analysis, including all measures of the SCS and BCoS, was conducted with a varimax rotation to maximize orthogonality and Kaiser Normalization. Factors with an eigenvalue ≥ 1.0 were extracted and rotated. Since the overall sample size was limited, a conservative criterion was used to determine final factor structure. Measures with high (0.5 and above) communalities (i.e., the proportion of each variable's variance that can be explained by the principal components) were retained. Small coefficients (<0.3) were suppressed from the analysis. To avoid cross-loadings and maintain the highest loading of interrelated variables within a distinct cluster, a threshold of (>0.48) was chosen (Yong & Pearce, 2013), and variables were considered part of a factor if their factor loading was greater than 0.48.

c. Cognitive Predictors

To examine the association of cognitive measures loading with socio-cognitive measures within each factor was assessed in a series of regression analyses presented below to identify the variables can best predicts the social component impairments. The variables in each distinct factor that combines general cognitive domain with social cognition aspect was analysed; using the general cognitive domain as independent variable and the social cognitive aspect as dependent variables.

4.3 RESULTS AND DISCUSSION

The final rotated model of the factor analysis produced seven factors that accounted for 78% of the total variance in the patients' performance. It demonstrated a good fit with 33% non-redundant residuals. Interestingly, the model linked four factors to social cognition factors, independently including; factors 2, 3, 5, 7, which endorses the independence of most of the social components operations. In addition, the factors produced showed consistent variable overlap with clusters of the SCS, as expected only some variables from the SCC factor, and replicating the associations of mindreading factor, indicating common patterns of deficits across many stroke survivors. Only two measures from the SCC factor (emotion reading and humour) overlapped with episodic memory (recognition and decay) and spatial attention from the BCoS, these results interesting in the indication of largely independent processing of the social cognition dimensions. These results are largely consistent with evidence from Mehta et al. (2013) systematic review on schizophrenic samples who found 8 out of 9 studies supporting the distinction between social cognition and neuro-cognitive factors. Summary of the factors, eigenvalues and the variances explained are presented in **Table 4.1**.

Table 4.1 Principal Component Analysis for the SCS and the BCoS

Measures	F 1 Social Rules	F 2 Impulsivity	F3 Sequencing Behavior	F4 Social Memory	F5 Social Behavior	F6 Verbal Attention	F7 Mindreading
Motivation	0.930						
Desire	0.901						
Anger	-0.568	-0.436	-0.376				
Faux pas	0.483	0.375				0.319	-0.416
Impulsivity		0.900					
Proverbs		0.707	0.385				
False Belief	0.395	0.678					
Praxis			0.848				
Rule finding(EF)		0.327	0.797				
Episodic memory				0.816			
Spatial attention				0.724	0.454		
Story-decay memory	-0.329			-0.557		-0.451	
Humour		0.459	0.359	0.523			
Emotion Reading				0.482			
Cognitive Empathy					0.837		
Apathy			-0.342		-0.726		
Moral reasoning	0.420		0.315		0.518		
Psy. attitudes		0.304	-0.346		0.507		
Language						0.897	
Controlled attention	0.438					0.719	
Emotional Empathy							0.922
Intention	0.359				0.301		0.545
Eigen values	3.422	2.724	2.510	2.509	2.463	1.970	1.618
%Variance explained	15.553	12.384	11.408	11.404	11.197	8.952	7.355
Cumulative %	15.553	27.937	39.344	50.749	61.945	70.898	78.252

4.3.1 The Domain Structure of Social Cognition in Relation to Cognitive Deficits among Stroke Survivors

Factor 1 was labelled as ‘Social Rules’. This factor, which accounted for 15.6% of the variance explained, only loaded with social cognition components, and included motivation, desire, anger and faux pas. These components reflect abilities pertaining to understanding others basic drives and motivation. These abilities may constitute mechanisms that stroke survivors may resort to in order to understand social rules and to employ them in their social interactions. In terms of brain injuries, difficulties with interpreting others motivations may lead to simplified and incomplete analysis of social situations. The reversed associations between anger levels with the other measures in this factor may be a reflection of such difficulties due to frustration, for example (see Factor 1, **Table 4.1**).

Variables loaded onto Factor 2 explained 12.38% of the variance and was labelled ‘Impulsivity’. The factor included impulsivity (measured by Go/no-go task), figurative language (assessed with the proverbs comprehension task), and ToM (assessed with the false belief animation task). The loading of the Go/no-go task onto this factor may reflect the contribution of inhibitory control on performance, which may result in tendency to leap to conclusion rather than analysing the facts and details of the social situation (Samson, Houthuys & Humphreys, 2015).

Factor 3, labelled ‘Sequencing Behaviour’, accounting for 11.41% of the variance, consisted of two measures from the BCoS, namely rule finding accuracy and multi object use. These two measures account for controlled attention and praxis, respectively. The dominant ability captured in this factor is executive functioning, which according to the authors of the BCoS reflects one’s “ability to find rules in a sequence of stimuli and to switch mental set, when a rule changes” (Humphreys,

Bickerton, Samson & Riddoch, 2012, p.6). Specifically, the tasks assess the ability to select and sequence actions to accomplish a specific goal, and as such it is a crucial ability for the execution of skilled actions and everyday multi-step object use.

Factor 4, labelled ‘Social Memory’, combined two measures from the SCS and three measures from the BCoS, accounting for 11.40% of the variance. The factor loadings consisted of episodic memory (measured by story delayed recognition), spatial attention (assessed by the apple cancellation task), story decay (assessed by subtraction between immediate and delayed recognition), humour (measured with the joke formation task from the SCS), and finally emotion recognition (assessed with the emotion reading task). The episodic memory (Task recognition) which was provided with forced-choice discrimination on which items had previously been encountered.

Factor 5, labelled as ‘Social Behaviour’, explained 11.20% of the variances and included measures that are linked to social cognition components, independent of the cognitive factors. The factor consisted of cognitive empathy, apathy, moral reasoning and psychological attitudes recognition, and thus it may reflect one’s social tendency toward social interactions. Interestingly, variables of this factor reloaded together as in the previous principal component analysis presented in **chapter 3, Table 2** (SCS Factor 3 ‘Interest in Others’) confirming the interaction between these social cognition elements and the mutual effects between them.

Factor 6, labelled ‘Verbal Attention’, accounted for 8.95% of the variance and consisted of two measures from the BCoS assessing language (picture naming) and controlled attention (auditory attention accuracy). This factor depends widely on language abilities and memory. The picture-naming task taps visual object recognition, and involved approaching the conceptual knowledge of the object and name retrieval. The task assessing controlled attention integrated working memory,

selective and sustained attention. Here, the task consisted of a set of words, and the examinee had to respond when hearing specific words (sustained attention) and to avoid the distractors words (selective attention). By the end of the task, the examinee was required to recall target and distractor words (working memory).

Finally factor 7, labelled 'Mindreading, accounted for 7.36% of the variance, and included two measures from the SCS, namely intention recognition and emotional empathy. These measures reflect one's ability to speculate about others' intentions by analysing the facts of the social context and the associated mental states believed to represent the observed action. Since emotional empathy is a selective process rather than automatic (Baron-Cohen, 2012), individuals may tend to consider others intentions when they decide to empathise with others.

4.3.2 Cognitive Predictors Underlying Social Cognition Deficits

Here I set out to examine the association of cognitive measures loading with social cognition. This analysis could reveal the extent to which these cognitive measures are involved in socio-cognitive functioning. From the above factor analysis, only Factor 2 (Impulsivity) and Factor 4 (Social Memory) included cognitive and socio-cognitive measures that loaded together. The association of socio-cognitive measures with cognitive measures within each factor was assessed in a series of regression analyses presented below to identify the variables can best predicts the social component impairments.

Factor 2: Impulsivity

Here I set out to examine the association of false belief (FB) with figurative language and impulsivity. Pearson correlation showed no association between FB and age ($r=-0.16$, $p=0.41$) or years of education ($r=0.28$, $p=0.15$). A t-test also revealed

that there was no difference between male ($M \pm SD = 7.00 \pm 0.92$) and female ($M \pm SD = 7.00 \pm 1.16$) participants in performance on FB understanding ($p = 1.0$).

To examine the association of these variables, a multi-step regression analysis was conducted. First, I asked whether inhibitory control can predict FB performance: The Z-standardized score of the Go/no-go task was set as predictor and FB as the dependent measure. The analysis revealed a significant model, $F(2,25) = 8.43$, $p < 0.001$, $R^2 = 0.25$, explaining 25% of the variance. Parameter estimates showed that impulsivity was positively and significantly associated with the FB score, $\beta(se) = 0.482(0.166)$, $t = 2.90$, $p = 0.008$. From this result it can be concluded that impulsivity can predict FB performance.

Second, I asked whether inhibitory control can predict figurative language performance. The Z-standardized score of the Go/no-go task was set as predictor with Proverb task scores as the dependent measure. The analysis revealed a significant model, $F(1,25) = 7.892$, $p < .001$, $R^2 = .24$, explaining 24% of the variance. Parameter estimates showed that Go/no-go score was positively and significantly associated with the proverb scores, $\beta(se) = 1.122(0.4)$, $t = 2.809$, $p = .009$. From this result it can be concluded that impulsivity can predict figurative language performance.

Lastly, I asked whether, conversely, figurative language and FB can predict impulsivity. The Z-standardized FB and proverb task scores were set as predictors and Go/no-go task scores as the dependent measure. The analysis revealed a significant model, $F(2,24) = 4.969$, $p < .001$, $R^2 = .293$, explaining 29% of the variance. Parameter estimates showed that proverb and FB scores were not significantly associated with the Go/no-go scores, $\beta(se) = 1.275(1.085)$, $t = 1.176$, $p = .251$. This result showed that figurative language and FB cannot predict impulsivity.

Factor 4: Social Memory

I examined the association of humour (joke formation) and emotion reading with three cognitive factors from the BCoS, which included episodic memory, memory decay and spatial attention. First, Pearson correlation showed an association between emotion reading and years of education ($r=0.495$, $p=0.009$). A t-test also revealed better performance in male ($M\pm SD=3.55\pm 1.43$) compared to female ($M\pm SD=2\pm 1.16$) patients in joke-formation ($t=2.58$, $df=25$, $p=0.016$).

Next, I conducted a regression analysis in which I entered *humour* as a dependent variable and the Z standardized scores of episodic memory, memory decay and spatial attention as predictors while controlling for gender. This analysis revealed a significant model ($F(4,20)=3.69$, $p=0.021$, $R^2=0.425$), explaining 42.5% of the variance. Parameter estimates showed that only episodic memory was a positive and significant predictor of humour ($\beta(se)=0.758(0.331)$, $t=2.29$, $p=0.033$).

This analysis was repeated to examine the association of emotion reading with the Z-standardized scores of episodic memory, memory decay, and spatial attention as predictors, while controlling for years of education. This analysis revealed a significant model, $F(4,20)=4.06$, $p=.014$, $R^2=.448$, explaining 44.8% of the variance. Parameter estimates, however, showed that none of the three cognitive measures were associated with emotion reading.

Next, I performed multi-step regression to test cognitive variable association with emotion reading, solely, while controlling for years of education. The results showed that years of education best predicts reading emotions, followed by spatial attention. This analysis revealed a significant model, $F(2,22)=6.523$, $p=0.001$, $R^2=0.372$, explaining 37.2% of the variance. Parameter estimates showed that years of

education, $\beta(\text{se}) = 0.959(0.312)$, $t=3.08$, $p=0.006$, and spatial attention, $\beta(\text{se}) = 0.558(0.263)$, $t=2.124$, $p=0.045$, were positive and significant predictors of reading others' emotions.

In Chapter 3, the high rates in failing the SCC factor indicated that most of stroke patients may have difficulties in forming novel social knowledge due to general domain cognitive failure or due to neural disconnection impeding access to episodic memory. This assumption was confirmed to a large extent in the current chapter. First the results confirmed an association confirmed -in chapter 3- and repeatedly in literature between inhibitory control and false belief attribution (Samson, Houthuys & Humphreys, 2015), and revealed that inhibition control can predict patients' performance on belief attribution and figurative language. Also, level of education and spatial attention predict the ability to identify others' emotions, the association between education and reading emotions was found to be related to general intelligence relationship with RMET (Baker, Peterson, Pulos & Kirkland, 2014), and also processing emotional facial expressions has long been related to spatial attention (e.g. Holmes, Vuilleumier & Eimer, 2003), suggesting that spatial attention can modulate the structural encoding of faces. Finally, episodic memory can predict humour performance indicating that participants may fail to access stored knowledge and form a reference for comparing the mean of humour. The relationship between episodic memory and humour was confirmed in prior studies (e.g. Sambrani et al., 2014).

Taken together, the varimax rotated principal component analysis resulted in seven factors that, combined, explained 78.25% of the variance. These factors reflected social rules, impulsivity, sequenced behaviour, social memory, social behaviour, verbal attention and mindreading. A main finding that emerged from this

analysis was that the majority of social cognition measures clustered in factors independent from cognitive measures. This result suggests that aspects of social cognition may dissociate from core cognitive processes. However, two factors appear to be related to EF Factor 2 overlapped with impulsivity and Factor 4 with memory and spatial attention.

The findings of factor 2 ‘Impulsivity’ suggest that dissociation between age, gender, and education level with impulsivity were consistent with the results from the control group in (see **Chapter 2, Tables 2.5, 2.6, 2.7**). The investigation of multi-step regression of cognitive predictors of social cognition has shown that inhibitory control can predict FB and figurative language function, while, conversely, figurative language and FB cannot predict inhibitory control. This suggests inhibitory control is necessary for succeeding on understanding others’ belief and also to comprehend the figurative language, and when the go/no-go task is passed, we may expect to see good performance on the proverb and FB tasks. However, cases where the Go/no-go task is passed, but the figurative language and FB tasks are not, may indicate that the reason for failure cannot be attributed to poor inhibitory control, and that there are other reasons involved.

The associations between years of education and reading emotions was notable, $F=2.939$, $p=0.058$ among control group; however, not significant (see **Chapter 2, Table 2.6**). Although the emotion reading task was designed to avoid the limitations of RMET, this result is in line with, Baker, Peterson, Pulos and Kirkland’s (2014) meta-analysis study investigating the RMET relation to intelligence. After brain injuries, education appears to play a protective role for emotion recognition. As with many cognitive competences, this may be due to increased controlled processes and conceptualization abilities (see Le Carrent, Lafont, Mayo & Fabrigoule, 2003). The

results of the regression indicated that years of education was the best predictor of reading emotions, followed by spatial attention. That spatial attention was found to affect our perception to identify and distinguish between various facial expressions was unsurprising, since face processing strongly depends on allocation of spatial attention (Crist, Wu, Karp & Woldroff, 2007).

4.3.3 Conclusion

The aim of this chapter was twofold. The first aim was to understand the integrated relations between general cognitive domains functions and social cognition functions. The second aim was to analyse the pattern of mutual dysfunctional processes between these two domains to identify which domain general processes are necessary for social cognitive functioning. The factorial structure of combined cognitive and social cognition assessment revealed consistency with the former SCS domain structure, and distinguished between the independent and reliant social cognition abilities, and identified the specific domain of cognition necessary for normal operation. While the factor analysis revealed that social cognition aspects most likely tend to operate independently, some aspects of cognition, and especially inhibition control, working memory, attention and episodic memory were associated with social cognition deficits such that inhibitory control predicted performance on figurative language and belief attribution, spatial attention (and level of education) predicted reading others' emotions performance and episodic memory predicted humour performance.

CHAPTER 5

SOCIAL COGNITION DOMAIN DEFICITS: EXPLORING CONNECTIONAL ANATOMY RELATIONSHIPS

Synopsis

In Chapter 3, I have shown that social cognition deficits tend to cluster in four domains in which the profiles of stroke patient vary. These domains corresponded to (1) social cognition control SCC, (2) motivation, (3) interest in others IO, and (4) mindreading. The goal of this chapter is to provide insight into the anatomical associations of socio-cognitive functioning and in particular to each of the four domains. In this regard, I investigated the associations of the behavioural data with the quantified anatomy of the patients' lesions to identify potentially homogeneous affected tracks relating to the four factors of the Social Cognition Screen, a track-wise lesion-deficits analysis approach was used. This analysis revealed a unique association between distinct networks of white matter tracts and three factors of social cognition, namely; the fornix, hand superior U track and posterior segment of the cingulum damage predicted impairments of the SCC factor. The inferior longitudinal fasciculus (ILF), the 5th branch of the frontal insular track and the first, second and third branches of the superior longitudinal fasciculus (SLF) lesions predicted the performance of the motivation factor. As well as the anterior thalamic radiation damage predicted the performance of the IO factor.

5.1 INTRODUCTION

Patients with brain lesions provide a unique window into brain function; studying healthy participants highlights a range of regions critical for a specific cognitive function, while analysing patients' assessments can determine which region of the network is decisive to that specific operation, which may refine our understanding of the relationship between brain anatomy and function. In this chapter, I aimed at investigating the anatomical associations of socio-cognitive functions and the brain regions involved in each of the four Social Cognition Screen (SCS) factors/domains. In Chapter 3, I analysed multiple aspects of social cognition using factor analysis that resulted in four factors: social cognition control (SCC), motivation, interest in others and mindreading. Results from Chapter 4 suggest that aspects of the SCC factor tend to engage brain areas related to higher cognition (e.g. inhibition control, memory, spatial attention, education years). The dependency of some aspects of social cognition on domain general functions is in lines with previous functional studies. For example, Saxe, Schulz and Jiang (2006) found both domain-general and domain-specific cognitive resources are involved in theory of mind. Specifically, belief attribution was found to make use of brain areas linked to attention, response selection and inhibitory control, including the pre-supplementary motor area (pSMA), anterior cingulate cortex (aCC), the left and right intraparietal sulcus, the left and right frontal eye fields, the left and right frontal operculum, the left and right middle frontal gyrus, the right middle temporal gyrus, the left and right thalamus and the left and right midbrain. The brain regions associated with representations of others' thoughts included the posterior cingulate, the left and right temporoparietal junction (TPJ), the medial prefrontal cortex (mPFC), the right anterior superior temporal sulcus (raSTS), the left insula and the left and right amygdala.

It is important to highlight that brain imaging studies link diverse frontal, partial temporal, and limbic regions false belief attribution (see ‘areas in *frontal lobe*’: Döhnelt, et al., 2012; Happaney & Zelazo, 2004; Martín-Rodríguez & Lión-Carrión, 2010; Rowe, Bullock, Polkey & Morris, 2001; Sommer et al., 2007; Stone, Baron-Cohen & Knight, 1998, and ‘*parietal lobe*’: (Apperly, Samson, Chiavarino & Humphreys, 2004; Döhnelt, et al., 2012; Enrici, Adenzato, Cappa, Bara & Teltamanti, 2011; Gallagher & Frith, 2003; Saxe, Schulz & Jiang, 2006; Samson et al., 2004; Sommer et al., 2007, ‘*temporal lobe*’: Apperly, Samson, Chiavarino & Humphreys, 2004; Gallagher & Frith, 2003, ‘*limbic regions*’: Ball, Holland, Watson & Huppert, 2010).

It worth noting that this diversity of brain regions also applies to other aspects social cognition embraced by the SCS, and particularly the SCC factor. For example, emotional states attribution has been linked to the ‘*frontal lobe*’ (Adolphs, 2002; Turner et al., 2007), ‘*temporal lobes*’ (Adolphs, 2002), and ‘*limbic regions*’ (Adolphs, 2002; Adolphs & Tranel, 2003; Adolphs et al., 1999; Coccaro, McCloskey, Fitzgerald & Phan, 2007; Eres, Decety, Louis & Molenberghs, 2015; Feinstein et al., 2013; Gallese, Keysers & Rizzolatti, 2004; Rotshtein et al., 2010; Schienle, et al., 2002; Turner et al., 2007). With regards to the motivation factor—the second factor of the SCS—the orbitofrontal cortex (OFC) has been found to engage during both desire and motivation tasks (Kawadata & Zeki, 2008; Leotti & Delgado, 2011; Wang et al., 2004). The OFC also has been found to be involve in the ‘interest in others’ factor—the third factor of the SCS—and specifically during the processing of attitudes (Cunningham, Haas & Jahn, 2011), and apathy (Levy & Dubois, 2006). Apathy has also been associated with the activation of the thalamus (Ball, Holland, Watson & Huppert, 2010). In addition, cognitive empathy has been linked to engagements of the

ventromedial prefrontal cortex vmPFC, the SMA and the TPJ (Fan et al., 2011; Shamay-Tsoory, 2011). Finally, the mindreading factor the forth factor of the SCS—has been linked to the dmPFC in operating emotional empathy and intention (Enrici, Adenzato, Cappa, Bara, & Teltamanti, 2011); emotional empathy has also been associated with three other brain regions namely: the ACC (Shamay-Tsoory, 2011), the SMA (Fan et al., 2011), and the insula (Eres, Decety, Louis & Molenberghs, 2015; Fan et al., 2011).

Given the complexity of the cognitive functions are not subject to centralize in one area of the brain but rather a group of symptoms (neurological syndromes) linked to damage set of neural networks. Notably, some of brain regions found to engage aspects belonging to different factors of the SCS (e.g. the OFC contribution in processing aspects belonging to all factors), perhaps emphasises the significance of these regions for the social cognition functioning. The degree of their contribution and to what extent these regions are crucial for the functioning of the domains covers by each factor is yet to be determined. Also, it is unknown what other alternative regions might support the functioning of these domains in case of lesions. Another point to highlight is that the above studies investigated aspects of social cognition individually and none of them adopted factor analysis or other component analysis methods, with emphasis on select areas. Also, there are no studies that investigated the white matter tracks that connect these brain regions and networks together. Indeed, there is paucity in researches concerning the white matter tracks that contribute to the operation of both domain general and domain-specific functions. For instance, lesion to the anterior segment of the left arcuate fasciculus that connects the posterior portions of Broca's area and the sensory-motor cortex has been found to affect language production (Fridriksson et al., 2013), while the disconnection of the second branch of

the superior longitudinal fasciculus (SLF 2) that connects the inferior parietal and the dorsolateral prefrontal cortices has been linked to spatial neglect (Thiebaut de Schotten et al., 2014) and impulsive aggression (Lee et al., 2016). For instance, damage to Baroca's area, situated predominantly in the posterior inferior frontal gyrus of the left hemisphere is associated with aphasia which is characterised by various language function and speech impairments (Dronkers, Plaisant, Iba-Zizen & Cabanis, 2007). On a cognitive functioning level of hypertension patients, reduced integrity of bilateral SLF (generally without allocating specific branch of SLF) and deficits in functional connectivity in frontal and parietal lobes were linked to decline executive functioning (Li et al., 2015). Similarly, damage to the right hemisphere and specifically to ventral regions within the parietal, temporal, and frontal cortices of result in unilateral spatial neglect syndrome which is characterised by an inability to attend and report stimuli on the opposite side of the lesion site (Corbetta & Shulman, 2011).

Neurological syndromes following stroke have been explored by Corbetta et al. (2015) using factor analysis to reveal the multidimensional core underlying the deficits. In their study, they linked defected domains to disconnection in white matter tracts as they suggested that disconnected white matter bundles could explain variance in the behavioural deficits of patients. Specifically, Corbetta et al. analysed data collected from 67 post stroke survivors who were assessed on a set of cognitive measures including attention, language, memory and motor function. The results highlighted three factors reflecting (i) language and memory (including both verbal and spatial memory) which have been linked to damage in ventral and dorsal white matter of the left, frontal temporal and parietal cortices, (ii) indices of right hemisphere damage (left motor impairment, bias against the left field, general

performance and spatial memory), and (iii) indices of left hemisphere damage (right motor impairment, bias against the right field and poor attention shifting).

In an analysis focusing on language functions in left hemisphere stroke patients, Butler, Lambon Ralph and Woollams (2014) reported three underlying factors that linked phonology, semantics and executive cognition to a specific white matter tract damage as well as cortical and limbic regions. In their study, the ‘phonology’ factor corresponded to the arcuate fasciculus component of the dorsal language pathway, the ‘semantic’ factor was uniquely related to left anterior middle temporal gyrus, and the underlying temporal stem broadly corresponded to the ventral language route. The third factor, ‘executive’ cognition, which explained the least variance, did not uniquely relate with any brain regions in their analysis. Alternatively, executive function deficits in relation to abnormalities in white matter tracts was studied by Koini and colleagues (2016) who studied a cohort of adolescent patients with Neurofibromatosis type 1 (NF1—a disease associated with executive functions impairments including working memory and inhibition control deficits. They examined white matter integrity of anterior thalamic radiation (ATR), cingulate bundle (CB), and superior longitudinal fasciculus (SLF) and found that damage to the ART damage was most strongly associated with inhibitory control, leading the authors to attribute a strategic role to the ATR in executive functioning.

However, in the field of socio-cognitive neuroscience, using a data reduction approach has been less evident and the vast majority of studies examined performance at the level of individual tests (more details are available in **Chapter 1**). Nevertheless, there are some indications from work within clinical population. For example, Downey et al., (2015) studied impaired social cognition in FTLN in relation to the damaged regions and the integrity of white matter connections. They assessed social

cognition with ‘emotion identification’ and ‘sarcasm identification’ subtests derived from ‘The Awareness of Social Inference Test’ (TASIT). In addition, they used Diffusion tensor imaging (DTI) to extract white matter tract associations with social cognition performance. The impaired social cognition performance was associated with distributed and overlapping white matter tract alterations specifically affecting frontotemporal connections in the right cerebral hemisphere. Specifically, emotion identification was linked to the anterior thalamic radiation ATR, and sarcasm identification was linked to the fornix and the uncinate fasciculus. The authors noted that the most active white matter correlation of emotion and sarcasm operation were entwined with tracts formerly involved in associating cognitive and evaluative functions related to emotion responses, as a part of a broad range of cognitive operations corroborated by these tracts. However, it is an open question as to how well these analyses apply to patients with sudden organic brain lesions due to stroke rather than progressive collapse of the brain mechanisms due to degenerative disorders. Interestingly, the association between sarcasm and uncinate fasciculus—a bundle that connects the OFC to the temporal pole—has also been linked to episodic memory (Von Der Heide, Skipper, Klobusicky, & Olson, 2013). This is commensurate with our findings in Chapter 4 where I have reported a link between humour formation and episodic memory. Taken together, this evidence suggests that the uncinate fasciculus is part of a neural network that supports the SCC factor. Another segment of this network may be the fornix that acts as a major output tract of the limbic system, which involved in most aspects comprising the SCC factor, including attributing others thoughts (Saxe, Schulz & Jiang, 2006), emotional state attribution (Adolphs, 2002), impulsivity (Medford & Critchley, 2010) and impulsive aggression (Coccaro, McCloskey, Fitzgerald & Phan, 2007). Moreover, episodic

memory has also frequently been linked to fornix damage (Ly et al. 2016; McMackin, Cockburn, Anslow & Gaffan, 1995). Another part of this network could be the Hand U-shaped tracks, which run beneath the central sulcus from the parietal postcentral gyrus to the frontal precentral gyrus (Rojkova et al., 2016) and may support the role of the dmPFC in processing the SCC factor. Nonetheless, despite the importance of white matter tracts underlying social cognition functions related to the SCC factor, there remains a paucity of information regarding the association of tracts to other factors of social cognition.

People tend to understand other's behaviour by automatically analysing their motivation behind specific conduct, and this is probably due to our tendency to direct our behaviour towards fulfilling goals that are identical among the majority of people. Accomplishing goals result in gaining positive emotions that serve as incentives for desired goals and form the reward function. Rewards can be primary and non-primary; primary rewards are driven to satisfy basic desires such as food and drink, and non-primary rewards require further appreciation beyond the processing of sensory components like money and sleek cars. Schultz (2015) suggests the key substrates for the brain's function in reward are specific neuronal network including midbrain dopamine neurons, striatum, amygdala and the OFC. The motivation factor, as explained in previous chapters, represented the affective ToM assessment especially that factor' tasks designed -in this thesis- with consideration to reduce the inhibition demands; as the participants asked about their own desire before making the attribution, in order to inspire them to distinguish between self-desire/ self-motivation and others desire and motivation. Processing affective social cues has long been associated with the insula including representations of content of other's thoughts (Saxe, Schulz & Jiang, 2006), empathy (Eres, Decety, Louis &

Molenberghs, 2015; Fan et al., 2011), impulsivity and inhibition control (Medford & Critchley, 2010). In their model of mentalizing circuits, Abu-Akel and Shamay-Tsoory (2011) suggest that affective ToM is mediated by a network that engages the ventral striatum, amygdala, ventral temporal pole (vTP), ventral anterior cingulate cortex (vaCC), the OFC, the vmPFC, the inferolateral frontal cortex (ILFC), the superior temporal sulcus (STS) and the TPJ. These diverse regions are supported by a set of association white matter pathways such as the superior branch of SLF1 that runs from the superior parietal lobule and the precuneus to the superior frontal gyrus (SFG); the SLF2 that connects the angular gyrus to the posterior regions of the middle frontal gyrus; the inferior branch SLF3 which starts in the supra marginal gyrus and terminates in the pars opercularis, triangularis and the inferior frontal gyrus (Rojkova et al., 2016). Another association track that might support this process is the Inferior Longitudinal Fasciculus (ILF) that connects the temporal and the occipital lobes together. The ILF has been found to impact have on operating the emotional valence of visual stimuli, by mediating the transmission of the stimuli to anterior temporal regions and neuromodulatory back-projection from the amygdala to early visual areas (Catani et al., 2003), the ILF was also found to predict mentalizing abilities and self-reported autism trait (Bradstreet, 2014). Another pathway that supports the connection between the inferior frontal gyrus (IFG) to the limbic region is the Fronto-Insular Tracts (FIT) which is the U-shaped tracts that connect insular cortex with various regions of the frontal operculum (Catani et al., 2012; Rojkova et al., 2016). This system of U-shaped fibres organised around the peri-insular sulcus connects the IFG and the pre-central gyrus (PrCG) to the insula. Anterior to this tract is a group of four U-tracts connecting the PrCG and the pars opercularis, pars triangularis and pars orbitalis of the IFG to the insular gyri (Catani et al., 2012).

An important region for processing social appropriate behaviour and belief attribution is the thalamus. It has been found to be engaged during attention, response selection and inhibitory control (Saxe, Schulz & Jiang, 2006), abilities that are important for social functioning, and among patients' cohorts was linked to disrupted mentalizing processes such as apathy and socially inappropriate behaviour (Ball et al., 2010; Mamah et al., 2010). Frontal projection tracts and especially the ATR that connects the fronto-thalamic and fronto-striatal projections pass through the anterior limb of the internal capsule and projects to the whole surface of the frontal lobe.

Another key brain region to social cognition functioning and joint attention is the STS; the sulcus separating the superior temporal gyrus from the middle temporal gyrus. The right posterior of the STS was active during the processing emotional empathy (Carr, Iacoboni, Dubeau, Mazziotta & Lenzi, 2003) as well as intention attribution (Carter, Hodgins & Rakinson, 2011; Enrici, Adenzato, Cappa, Bara, & Teltamanti, 2011) that form the mindreading factor of the SCS. Rojkova et al. (2016) in their investigation of frontal lobe neural connection suggested that parts of the posterior STS is supported by the 'arcuate fasciculus'; a sidelong association track that constitutes of long and short fibres linking the perisylvian cortex of the frontal, parietal, and temporal lobes (Catani & Thiebaut de Schotten, 2008).

The 'arcuate fasciculus long segment' (FALs) is arching around the Sylvian fissure, which separates the frontal and the parietal lobes superiorly from the temporal lobe. The fronto-temporal portion of the arcuate fasciculus connects the pars opercularis (i.e., Broca) to the auditory cortex and the posterior portion of the middle and inferior temporal gyri. Shorter fronto-parietal bundles link the ventral portion of the precentral gyrus to the postcentral gyrus and the supramarginal

gyrus. These branches form the ‘anterior segment’ of the arcuate fasciculus (Rojkova et al., 2016). The arcuate fasciculus is linked to several cognitive functions including the left hemisphere bundle which linked to some aspects of language (Catani et al., 2005; Catani & Mesulam, 2008; Fridriksson et al., 2013). The arcuate fasciculus of the right hemisphere was found to also play a role in visuospatial processing (Thiebaut de Schotten et al., 2008).

To best of my knowledge, there are no studies that investigated white matter damage concurrently with social cognition deficits in a cohort of post-stroke survivors. Here, I explore neuroanatomical basis of post stroke impairments of social cognition by the mean of underlying latent factors affected by brain damage, in order to potentially link between damage of specialised brain regions, including the underlying white matter neuro-circuits, and social cognition impairment. To address this goal, a dual strategy for the analysis has been adopted: (i) a voxel lesion symptom mapping (VLSM) analysis, and a (ii) track-wise lesion-deficit analysis. Regarding the VLSM, the study’s sample is volunteers patients sample with inhomogeneous focal lesions and include a set of lesions that cover the entire brain, an aspect that might affect the results of the small sample size, possibly due to losing the overlapped voxels (Baldo, Wilson & Dronkers, 2012). The alternative strategy is based on the fact that in a brain composed of localized but connected specialized areas, disconnection leads to dysfunction (Catani & ffytche, 2005), as a track is considered disconnected when a patient’s lesion overlapped with a voxel at a probability exceeding 50% of a given track (Chechlaz; 2015; Thiebaut de Schotten et al., 2011; Thiebaut de Schotten et al., 2014). This method helps to identify the white matter pathways that key for a specific social cognition function through statistical methods even in cases in which there is no overlap.

It is hypothesised that (i) a white matter network consisting of the uncinate fasciculus, fornix, hand U shaped tracks, anterior thalamic radiation (ATR), cingulum bundle (CB), and the superior longitudinal fasciculus (SLF) may predict deficits in Factor 1 of the SCS, namely, the factor of social cognitive control; (ii) A ventral anterior more distributed network might be involved in motivation factor process that connect the ventral striatum, amygdala, ventral temporal pole (vTP), ventral anterior cingulate cortex (vaCC), the OFC, the vmPFC, the inferolateral frontal cortex (ILFC), the superior temporal sulcus (STS) and the TPJ (Abu-Akel & Shamay-Tsoory, 2011). A set of disconnected white matter pathways including the Inferior Longitudinal Fasciculus (ILF), the Fronto-Insular Tracts (FIT) and the SLF theoretically might predict the deficits on motivation factor; (iii) the thalamus has been linked to various impaired social behaviour (Ball et al., 2010; Mamah et al., 2010), which forms the main feature of the ‘interest in others’ OI factor. The ATR that pass through the anterior limb of the internal capsule and projects to the whole surface of the frontal lobe is hypothesized to predict the impaired performance of the IO factor; and finally (iv) the lesions of the anterior and the long segments of the right arcuate fasciculus may predict deficits on the mindreading factor; this is based on the ‘arcuate fasciculus’ support the STS (Rojkova et al., 2016), and the right STS link to processing emotional empathy (Carr, Iacoboni, Dubeau, Mazziotta & Lenzi, 2003) as well as intention attribution (Carter, Hodgins & Rakinson, 2011; Enrici, Adenzato, Cappa, Bara, & Teltamanti, 2011) that form the mindreading factor.

5.2 METHODS

Participants

Twenty-six post stroke survivors with heterogeneous stroke type and lesioned regions participated in this study. The cohort consisted of white English volunteers [19 (73%) males and 7 (27%) females]. Participants' age ranged from 31-86 years old ($M = 62.81$; $SD = 12.07$), and they received an average of 12 years of education ($M = 12.09$; $SD = 3.49$). All the patients were at a chronic stage of recovery from stroke (>9months post stroke). Participants gave informed consent in agreement with an ethics protocol approved by the U.K. National Research Ethics Committee, and were members of the patient panel at the Cognitive Neuropsychology Centre (CNC), Department of the Experimental Psychology-University of Oxford. Patients' clinical and demographic are reported in **Table 5.1**.

Participants were assessed on the Social Cognition Screen (SCS), which was designed as a part of my Doctoral research with the aim of developing a screen to detect socio-cognitive deficits after brain injury. The SCS encompasses 15 sub-scales/tasks, which were validated and standardized (see **Chapter 2** for more details on screen creation and psychometric features). A rotated principal component analysis extracted four factors of social cognition that correspond to (1) social cognition control, (2) motivation, (3) interest in others and (4) mindreading (see **Chapter 3** for more details).

Table 5.1 Patients' clinical and demographic data.

ID	Age	Gender	Lesion side	handedness	Stroke type	Onset (months)
P 3001	69	F	R	R	TACI	14
P 3053	54	M	B	R	POCI	13
P 3041	64	M	B	L	NA	18
P 2046	60	M	L	R	TACI	11
P 3030	67	M	R	R	MCA	10
P 2027	72	F	R	R	ACI	14
P 2022	62	F	L	R	PACI	10
P 3057	72	M	L	R	NA	13
P 2003	31	M	L	R	PACS	17
U21	61	M	R	R	NA	25
P 3012	44	F	L	R	MCA	12
P 3043	54	F	L	R	NA	13
P 3101	68	F	L	R	NA	13
P 3174	66	M	L	R	NA	14
P 3108	77	M	R	R	SAI	9
P 3038	58	M	L	R	ACI	17
P 3104	67	M	R	R	CVA	9
P 3076	63	M	B	R	LA	11
P 3079	63	M	L	L	LA	11
UB 11	44	M	L	R	NA	144
P 2019	86	M	R	R	ACI	14
P 2057	79	M	R	R	TACS	17
P 3089	69	F	B	R	CL	11
P 3102	79	M	R	R	PACS	10
P 2045	71	M	R	R	PACI	14
P 3178	48	M	L	R	NA	16

F= Female; M=Male; L=Left; R=Right; B=Bilateral; CVA = Cerebrovascular Accident, ICH = Lobar intracerebral haemorrhage, MCA = Middle Cerebral Artery, PTCA = percutaneous transluminal coronary angioplasty, TACI = Total Anterior Circulation Infarct, TACS = Total Anterior Circulation Stroke Syndrome, SAI=subacute infarct, LA=lacunar infarct, CL=cerebellar lesion, NA=not available.

Procedures

(a) Behavioural Measure

The raw scores of the patients on the SCS measures were converted into Z-scores, using the controls group mean and standard deviation across each factor. The calculation of the Z-scores were performed using the following standard formula

$$Z = \frac{(x - \mu)}{\sigma}$$

where (x) was the raw score of performance, (μ) was the mean of controls in that assessment and (σ) was the standard deviation of the controls' performance for the assessment. Cut-off scores for each factor were established as $\pm 2SD$ from the mean scores of the controls. The patients' raw scores also were converted to standardised scores, using the mean and standard deviation of the control group scores across each factor. The patients' performance on each factor where then classified based on the cut-off z-scores of the controls. The patients' and controls' performance on the SCS factors are depicted in **Figure 5.1**. The patients' and controls' Z-standardised scores on the four factors of the SCS are presented in **Table 5.2**. Scores that exceeded the cut-off scores are in **bold**.

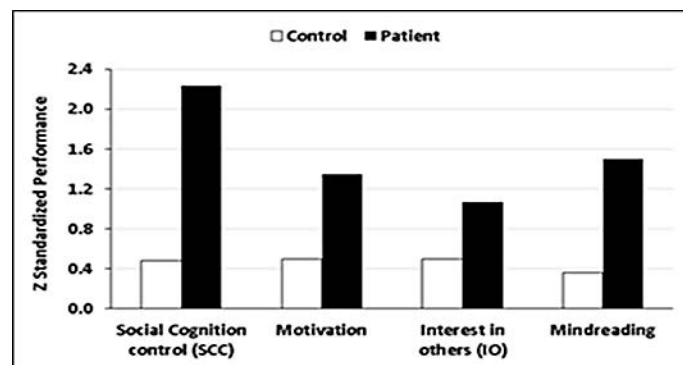


Figure 5.1 Patients and controls performance on the four factors of the SCS

Participants were assessed on the Social Cognition Screen (SCS), which was designed as a part of my Doctoral research with the aim of developing a screen to detect socio-cognitive deficits after brain injury. The SCS encompasses 15 sub-scales/tasks, which were validated and standardized (see **Chapter 2** for more details on screen creation and psychometric features). A rotated principal component analysis extracted four factors of social cognition that correspond to (1) social cognition control, (2) motivation, (3) interest in others and (4) mindreading (see **Chapter 3** for more details).

(b)The Delineation of Lesions

Brain imaging preparation for this study was conducted by the laboratory team of the Cognitive Neuropsychology Centre, Oxford University. Data processing was carried out using a specially developed toolbox for fully automated pre-processing and lesion mapping of brain CT scans (for full details see Gillebert et al., 2014, cited in Schechlac, et al., 2015). “Automated lesion delineation, for each post stroke survivor’s brain images, was processed through a voxel-based outlier detection procedure implementing the Crawford-Howell parametric t-test for single case-control comparisons.

The parametric t-test has been used to generate an outlier t-score map coding the degree of abnormality of each voxel compared to the normal range based on control CT scan. The t-score maps were thresholded to generate binary lesion maps in MNI space, which in turn were converted to the native CT space enabling the researcher to verify lesion reconstruction based on the original CT scan. The binary lesion maps for all patients were used in the track-wise lesion-deficits analysis to calculate lesion volumes”. Cases that were manually delineated were normalized into an age

appropriate template space using Chris Rorden's Clinical toolbox for SPM (Rorden et al., 2012).

5.2.1 The Voxel Lesion Symptom Mapping (VLSM) Analysis

We used 'behaviour-defined approach' where the continuous behavioural data and lesion information were analysed on a voxel-by-voxel bases. Patients were classified based on showing specific behavioural deficit, then lesion reconstructed maps of impaired patients were overlaid to find common lesioned areas and compared to lesion overlays from the patients without the deficits (see Adolphs et al., 2000; Thiebaut de Schotten et al., 2012).

In order to investigate the overlapped lesioned areas with poor assessment on the SCS domains, first we ran a classical VLSM analysis using MRICron program—a non-parametric mapping (NPM) approach for continuous variables, which employed the Brunner Munzel test and t-test among other statistics. Details of the program and analysis are available at (<http://www.cabiatl.com/mricron/npm/>). The statistical outcome maps identified the potentially associated voxels where it was or was not possible to detect effects at a minimum overlap threshold that had 10% of the cohort possessing a lesion on a given voxel and their distribution of the SCS scores.

5.2.2 Track-Wise Lesion-Deficit Analysis

In order to assess if there was a relationship between the amount of damage to a particular track (i.e., patient fractional score) and their assessment on each factor of the SCS, patients' lesion volumes were classified using Catani's atlas for fraction segmentation of white matter tracks (Rojkova et al., 2016; Catani & Thiebaut de Schotten, 2012). The lesion volumes were used linear regression, which was calculated using IBM's SPSS, version 21. The quantitative lesions data of the patients

are presented in continuous measures that have been classified based on the summary fraction lesion of Catani's atlas to 87 segments including association, commissural and projection pathways in left and right hemispheres. To identify whether white matter tracks damage were able to predict impairment of specific SCS factor, the patients' scores of the SCS factors were used respectively in each trial as dependant variables, while the total lesion size and age were controlled and covariates in all the trials, in addition to the hypothesised tracks' quantitative volume. For a more conservative approach, the significant regression models that accounted for lesion size merely without the tracks were omitted.

5.3 RESULTS

5.3.1 Behavioural Measures

Table 5.2 The patients' Z-standardised scores on the four factors of the SCS, the impaired scores are highlighted in **Bold**

ID†	Factor 1 Social cognition control cut-off Z-score (0.85)	Factor 2 Motivation cut-off Z-score (1.49)	Factor 3 Interest in others cut-off Z-score (0.86)	Factor 4 Mindreading cut-off Z-score (1.17)
P 3001	4.925	3.950	1.750	1.8
P 3053	5.880	6.005	2.395	2.34
P 3041	1.182	2.810	1.561	3.96
P 2046	3.846	8.290	0.623	2.34
P 3030	1.072	0.395	1.066	3.96
P 2027	3.921	0.395	1.920	2.34
P 2022	1.710	1.080	0.991	2.34
P 3057	1.676	2.810	0.500	3.96
P 2003	1.101	0.395	1.426	0.95
U21	1.348	0.395	1.081	0.41
P 3012	2.821	0.395	1.333	0.41
P 3043	2.280	1.780	0.293	0.41
P 3101	1.064	0.395	1.093	0.95
P 3174	1.101	0.395	0.866	0.95
P 3108	5.585	0.395	0.940	0.41
P 3038	1.101	0.395	1.006	0.95
P 3104	4.515	0.395	0.700	2.34
P 3076	2.460	0.395	2.570	0.41
P 3079	1.020	0.395	0.628	1.8
UB 11	1.590	0.395	0.676	0.95
P 2019	2.601	1.095	0.736	0.41
P 3089	1.851	0.395	0.260	0.41
P 3102	1.724	0.395	0.860	0.41
P 2057	0.692	0.395	2.106	0.95
P 2045	0.760	0.395	0.456	1.8
P 3178	0.740	0.395	1.153	0.95

† The order of patients is based on the number of malfunctioning factors.

5.3.2 The VLSM

The VLSM analysis that runs per voxel using full lesion masks did not yield significant results. This is probably due to the small sample size and the heterogeneity of the site of the stroke (Baldo, Wilson & Dronkers, 2012). Lesion overlap images for the whole cohort are presented in **Figure 5.2**. As it can be seen in Figure 5.2, the cohorts' lesion covered quite a diffuse area and did not have a high degree of overlap; maximum 7 patients with 67.94% of patients overlap, **Table 5.3**.

5.3.3 Track-Wise 'Hodological' Lesion-Deficit Analysis

To overcome the spatial heterogeneity, and to identify the tracks whose lesion had a predictive value, the fractional values of white matter tracks were used to investigate the associations between severity of the white matter tracks damage and SCS factors deficits.

5.3.3.1 The Predictors of Social Cognition Control Factor (SCC)

A linear regression was performed to identify tracks that are associated with SCC factor scores. The age and total lesion size was controlled as independent variables, because in previous study by Karnath, Frhmann, Berger, Küker and Rorden (2004) found that using lesion size as a regressor in the voxel-wise analysis undermines the findings so they do not survive the correction for multiple comparisons. The analysis revealed that damage to the left and right bundles of the uncinate fasciculus was unrelated to the SCC factor ($F(4,21)=0.170$, $p<0.591$, $R^2=0.031$). There was also no association between the left or right Anterior Thalamic Radiation (ATR) bundles and the SCC factor ($F(4,21)=0.240$, $p<0.912$, $R^2=0.044$).

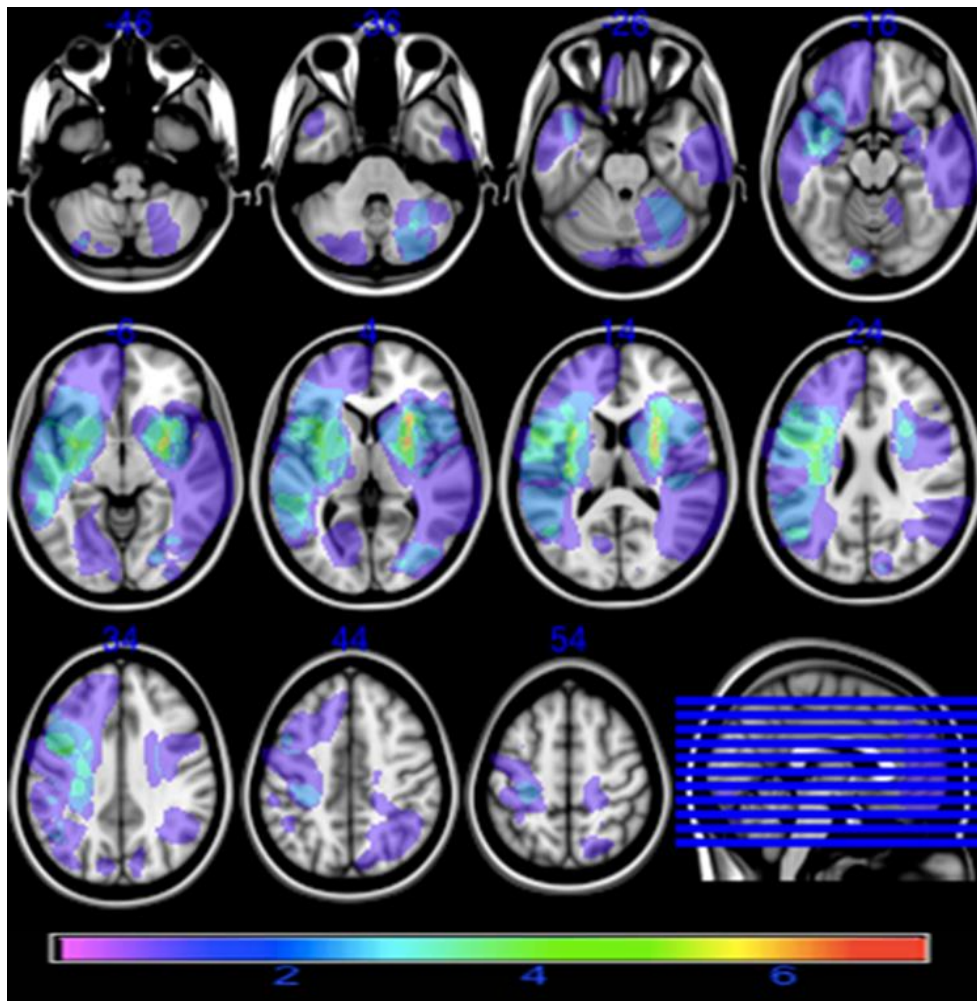


Figure 5.2 Lesion overlap for stroke participants (N=26)

Table 5.3 Voxels overlap for the whole cohort (N=26)

Number of Patients	Number of voxels covered by overlap	% of patients lesion overlap
1	61283	67.935
2	19516	21.635
3	7104	7.875
4	1798	1.993
5	395	0.438
6	101	0.112
7	10	0.011

However, the ‘fornix’ and the ‘hand superior U track’ together significantly predicted patients’ performance on SCC factor. The results of the regression indicated that the two predictors explained 49.4% of the variance ($F(4,21)=5.135$, $p<0.005$, $R^2=0.494$). Specifically, the fornix ($\beta(\text{se}) = -58.548 (20.357)$, $t = -2.876$, $p=0.009$) and the hand superior U tract ($\beta(\text{se}) = -45.636 (12.118)$, $t = -3.766$, $p=0.001$) were negatively associated with performance on the SCC factor.

Applying the same analysis to the left and right sides of the posterior segment of the cingulum tracks, the results yielded a significant model, explaining 36% of the variance ($F(4,21)=2.883$, $p<0.048$, $R^2=0.335$). However, only the right bundle of the track showed significant negative association with performance on the SCC factor ($\beta(\text{se}) = -195.78 (63.73)$, $t = -3.072$, $p=0.006$), while the left bundle association was non-significant ($\beta(\text{se}) = 72.67 (84.69)$, $t = 0.858$, $p=0.401$).

With respect to the right and left hemispheres of the first, second and third branches of the superior longitudinal fasciculus (SLF), the analysis showed on a marginally significant model ($F(4,21)=2.375$, $p<0.085$, $R^2=0.312$), explaining 31% of the variance. Parameter estimates, however, suggested a significant negative association between only for the first right SLF tract (SLF1R) and performance on the SCC factor ($\beta(\text{se}) = -54.74 (18.63)$, $t = -2.938$, $p=0.008$).

5.3.3.2 The Predictors of the Motivation Factor

Regression analyses exploring predictors of performance on the motivation factor resulted in several significant models. First, the regression analysis of the ‘Inferior Longitudinal Fasciculus’ (ILF) yielded a significant model ($F(4,21)=4.962$, $p<0.006$, $R^2=0.486$), explaining almost 49% of the variance. It showed a positive significant association between performance on the motivation factor and the left bundle of the

inferior longitudinal fasciculus ($\beta(\text{se}) = 6.85(2.21)$, $t=3.01$, $p=0.005$), while the right hemisphere bundle did not reach significance ($\beta(\text{se}) = 2.28(1.48)$, $t=1.54$, $p=0.138$). Moreover, the investigations of ‘the fronto-insular tracts’ (FIT) included 5 tracks bilaterally (10 tracks all together). Using backward regression, the analysis revealed a significant model explained 53% of the variance ($F(4,21)=5.913$, $p<0.002$, $R^2=0.53$). The third track bilaterally was marginally associated with the performance on the motivation factor: ‘left fronto-insular track (FIT3L) ($\beta(\text{se}) = -1.746(0.968)$, $t=-1.804$, $p=0.084$), and the right bundle (FIT3R) ($\beta(\text{se}) = 1.23(0.674)$, $t=1.829$, $p=0.082$). However, there was a significant association between the left bundle of the fifth track (FIT5L) ($\beta(\text{se}) = 4.518(1.282)$, $t=3.524$, $p=0.002$) and performance on the motivation factor. In addition, an analysis investigating the association of the first bundle of ‘the superior longitudinal fasciculus tract’ (SLF1) bilaterally, produced a significant model explaining 65% of the variance ($F(4,21)=9.77$, $p<0.0001$, $R^2=0.650$). It was found that the left ‘SLF1’ tract ($\beta(\text{se}) = -16.837(4.73)$, $t=-3.56$, $p=0.002$), as well as the right ‘SLF1’ tract ($\beta(\text{se}) = -20.701(5.147)$, $t=-4.02$, $p=0.001$) were significantly and negatively associated with performance on the motivation factor. Similarly, the analysis of the left and right branches of SLF2 and SLF 3 together yield a significant model that explained 47% of the variance ($F(6,19)=2.836$, $p<0.038$, $R^2=0.472$). The SLF2R tract was negatively associated with performance on the motivation factor ($\beta(\text{se}) = -19.945(8.31)$, $t=-2.399$, $p=0.027$), while the left branch association was not significant ($\beta(\text{se}) = -1.79(5.90)$, $t=-0.303$, $p=0.765$). With regard to the SLF3, also the right branch association was positively significant ($\beta(\text{se}) = 8.265(3.69)$, $t=2.24$, $p=0.037$), while the left branch did not yield significant result ($\beta(\text{se}) = -0.196(5.60)$, $t=-0.075$, $p=0.941$).

5.3.3.3 The Predictors of the Interest in Others (IO) Factor

The regression analysis for the IO factor and the ‘Anterior Thalamic Radiation’ track (ATR) bilaterally resulted in a significant model explaining 38% of the variance, ($F(4,21)=3.268$, $p=0.031$, $R^2=0.384$). The parameter estimates showed that only the right bundle of the ATR was significant, and negatively associated with performance on the IO factor ($\beta(\text{se})= -40.57(13.42)$, $t=-3.02$, $p=0.006$), while the left branch association was not significant ($\beta(\text{se})= 6.86 (4.94)$, $t=1.391$, $p=0.179$).

5.3.3.4 The Predictors of the Mindreading Factor

The regression analysis for the right branches of the ‘arcuate fasciculus’ anterior and ‘long segments’ with mindreading factor did not yield significant results ($F(4,21)=2.218$, $p=0.102$, $R^2=0.297$). However, there was a suggestive negative association between the arcuate anterior segment ($\beta(\text{se})= -2.091 (1.107)$, $t=-1.889$, $p=0.073$) and performance on the mindreading factor, and the arcuate long segment ($\beta(\text{se})= -3.021 (2.189)$, $t=-1.38$, $p=0.182$).

5.4 DISCUSSION

The aim of this study was to explore the link between social cognition domains and anatomical brain regions. In the first step, a VLSM approach was carried out with a ‘behaviour-defined approach’ where the continuous behavioural data and lesion information were analysed on a voxel-by-voxel bases. This approach did not produce significant results. This is more likely because the methodology of the VLSM relies on identifying voxels that are significantly related to a particular behaviour of interest in a group of patients, and involves running a statistical test (e.g., a t-test) at every voxel, comparing scores on a behavioural measure (e.g. the SCS factors scores) in

patients with versus patients without a lesion in particular voxel. This procedure might result in losing the overlapped voxels by adding data of patients who might not have the exact lesion localization and size (Baldo, Wilson & Dronkers, 2012). However, the anatomical location of overlapping lesions of the sample mostly accumulated in sub-cortical areas and medial frontal subcortical regions (Figure 5.2), including the putamen, insula, pallidum, heschl, amygdala, thalamus, extreme capsule, external capsule and the internal capsule, as well the location of the Superior Longitudinal Fasciculus and the superior occipitofrontal fasciculus (Woolsey, Hanaway & Gado, 2008). In addition, the overlapping lesions also included some cortical areas including the insular, central opercular and frontal operculum cortices and the angular, inferior frontal, middle temporal, precentral, postcentral and superior temporal gyri. However, while the pattern of lesion may reflect the type of stroke, it may not prove the impact of the lesion on the mechanisms.

To overcome the spatial heterogeneity, and to identify potentially homogeneous affected tracks relating to the SCS factors, a track-wise lesion-deficits analysis approach was also conducted. As stated above, this approach relies on describing the disconnection caused by lesion at individual level. A tract is considered disconnected when a patient's lesion overlapped on a voxel with probability exceeding 50% to a given tract (Chechlaz; 2015; Thiebaut de Schotten et al., 2011; Thiebaut de Schotten et al., 2014). The fractional values from white matter tracks was used in regression analysis to look for relationships between severities of white matter track damage and impaired social cognition factor assessment. The results revealed several significant models indicating that the majority of the influential tracts belonged to frontal lobe circuits and which in particular connect the frontal, parietal and temporal lobes together (Rojkova et al., 2016). The diversity in the white matter tracks associated

with different factors suggests the diversity of domain specific operations that underlie various social cognition factors.

(a) White matter tracks linked to the SCC factor

The results revealed a right hemisphere network consisted of the fornix, the cingulum posterior segment, the hand superior U-shaped tract, and the first branch of the superior longitudinal fasciculus. The fornix connects that frontal, temporal lobes and limbic organs together, the cingulum posterior segment comprises of fibre bundles of different lengths and runs within the cingulate gyrus to the all-around the corpus callosum, and the longest fibres run from the para-hippocampal gyrus and the uncus to the medial portion of the OFC (Rojkova et al., 2016). It also contains short U-shaped fibres that link the medial frontal and parietal to different portions of the cingulate gyrus (Rojkova et al., 2016), and the hand superior U-shaped track which runs beneath the central sulcus from the parietal postcentral gyrus to the frontal precentral gyrus (Catani et al., 2012; Rojkova et al., 2016), finally the superior branch of SLF1 that runs from the superior parietal lobule and the precuneus to the superior frontal gyrus (SFG) (Rojkova et al., 2016).

This central oriented white matter network connected the limbic, sub-cortical and cortical region subserving regions belonging to the frontal, partial and temporal lobes which are involved in various social cognition functions related to the SCC factor. These regions include the dmPFC, dACC, PFC, R-STG and R-TPJ that have been linked to false belief attribution (Dohnel et al., 2012; Gallagher & Frith, 2003; Saxe, Schulz & Jiang, 2006; Sommer et al., 2007); the OFC which has been linked to moral reasoning (Mendez, 2009), the right dPFC, inferior parietal circuits, pre-SMA, and ACC, which have been linked to inhibition (Medford & Critchley, 2010; Scheffer, Monteiro & Martins de Almeida, 2011; Simmonds, Pekar & Mostofsky, 2008).

Moreover, the superior frontal gyrus (SFG) has been linked to humour comprehension (Chan et al., 2013; Shibata et al., 2014); the PFC which has been linked to reading emotions (Tsuchida & Fellows, 2012); limbic regions which have been linked to emotional state attribution (Adolphs, 2002; Gallese, Keysers, & Rizzolatti, 2004; Schienle, et al, 2002); and frontal and temporo-parietal regions which have been linked to impulsive aggression (Lee et al., 2016).

To sum up, this investigation provides support for the predictability of the integrity of the fornix, cingulum, the hand superior U-track and the SLF1 of deficits in social cognition control. Difficulties with social cognition control (the SCC factor) have been linked to fornix white matter disconnection, which previous studies have linked to memory (Ly et al. 2016; McMackin, Cockburn, Anslow & Gaffan, 1995). This may suggest that processes of the SCC factor are affected by the retrieval of information, in addition to inhibition control.

(b) White matter tracks linked to the motivation factor

The results point to an association of a distributed bilateral network of white matter tracks with dysfunction in the motivation factor; There white matter tracks include the right branch of the ILF, the left 5th branch of the FIT, the first branch of SLF bilaterally and the right hemisphere second and third branches of the SLF. This distribution and multiplicity of the white matter networks subserving the ‘Motivation’ factor could explain this factor’s resistance to the adverse effects of stroke. Also some regression model illustrated positive associations of some of these predictors, which may indicate the over load on these tracks as a result to the brain tissue lesions due to the stroke. For instance, the ILF fibre bundle that connects occipital lobe with the anterior part of the temporal lobe (Ashtari, 2012), has impact on operating the emotional valence of visual stimuli, by mediating the transmission of the stimuli to

anterior temporal regions and neuromodulatory back-projection from the amygdala to early visual areas (Catani et al., 2003), supports a number of areas more classically associated with vision as well as affective mentalizing circuits including the ILFC, STS and the vTP (Abu-Akel & Shamay-Tsoory, 2011), and perhaps damage to adjacent regions such as amygdala (linked to both reward and mentalizing operations) could impose burden on the ILF track resulting in impaired performance of this factor, and the same assumption could be made on the FIT-5 track relation to the insula. Interestingly, the disconnection of both left and right bundles of the SLF1 predicted the defected performance on this factor, which may constitute a main carrier in processing the operation of this factor. The SLF1 also produced a marginal significant model that associated negatively with the SCC factor, given that results of correlation between factors (see CH3) showed significant positive correlation between SCC and motivation factor, however, the regression model did not support the prediction relation between these factors, this relation may explain the contribution of SLF1 to both factors. In their atlas to the frontal lobe, Rojkova and colleagues (2016), suggest that the SLF is a system composed of three parallel longitudinal branches passing through the dorsolateral portion of the white matter, situated above the ventricles and the lateral sulcus, and connecting the parietal and the frontal lobes. The SLF1 runs from the superior parietal lobule to the SFG, supports areas related to mentalizing and reward processes. On a cognitive functioning level, bilateral SLF was linked to attention and executive functioning (Li et al., 2015).

The second branch SLF2 that connects the angular gyrus to the posterior regions of the middle frontal gyrus supports regions related to affective mentalizing (e.g., desire) including the TPJ (Chiavarino et al., 2010). On a cognitive level, SLF2 was linked to dysfunction of parietal frontal circuits that result in left spatial neglect

(Thiebaut de Schotten et al., 2014). Lastly, the inferior branch SLF3, that starts in the supra marginal gyrus and terminates in the pars opercularis, triangularis and the inferior frontal gyrus (Rojkova et al., 2016), sub-serving areas including the caudate, putamen and nucleus that has been related to motivation in previous studies (Leotti and Delgado, 2011).

(c) The white matter tracks predictor of interest in others (IO) factor

The result illustrated a significant impact of lesion to the right hemisphere branch of ‘anterior thalamic radiation’ (ATR), on performance on the IO factor. The ATR is a fibre pathway that passes through the anterior limb of the internal capsule and projects to the whole surface of the frontal lobe, involving a reduced probability for the ventral portion of the precentral gyrus and the middle frontal gyrus (Catani, 2012; Rojkova et al., 2016). It plays a critical role in transmitting cognitive, sensory and motor information between the thalamus and cortical areas. The predictive relation between the deficit on IO factor and the disconnection of the ART might be due to the role of ART in facilitating somatic, sensory, and motor representation of other peoples' mental states, and the thus damage to this track could result in poor mirroring and mentallizing of the observed mental and bodily states. In a previous study, degradation of the ATR has been evident in patients with Parkinson disease (Planetta et al., 2013), and this evidence might support the deficit of the kinetic aspects of social cognition behaviour presented in IO factor. Studies of cognitive empathy have also been linked to cortical areas including midcingulate cortex (MCC) and dmPFC (Fan et al., 2011; Eres, Decety, Louis & Molenberghs, 2015), the fusiform gyrus that involve in face and body perception and the premotor cortex that associate with mirroring and imitating of others' actions, as well as limbic regions including the thalamus (Nummenmaa, Hirvonen, Parkkola & Hietanen, 2008). Apathy has been

linked to frontal lobe and to bilateral basal ganglia damage (Hama et al. 2011), in addition to the thalamus (Ball et al., 2010). The right branch of ATR as a projection track perhaps is main tributary that connects the diversity of brain regions involved in this factor's variables.

(d) The white matter tracks related to the mindreading factor

The results did not find robust associations between the Arcuate Fasciculus (AF) and Mindreading (the 4th social cognition factor). However, there was a marginal negative association between the anterior and long segments and performance on the mindreading factor. This result might change with bigger sample size study. Future studies need to consider further investigations to identify the tracts supporting the STS in addition to brain regions responsible for automatic cognitive operations underpinning social cognition such as ACC, Pre-SMA and basal ganglia (Satpute & Lieberman, 2006; Saxe, Schulz & Jiang, 2006).

5.4.1 Limitation and future research

The most limitation of this study was the number of participants as with newly established assessment tool, it is important to assess a larger group of patients for better emerging of the variation between the samples' members. These results therefore need to be interpreted with caution. Also for allowing the opportunity to divide the patients sample based on lesion site. Examining larger group also will provide more accurate overlap for the association of SCS factors with brain regions in a VLSM study and this will help to identify the white matter tracks more crucial for factors' operation. Future studies should consider examine whether reduced white matter integrity in other brain regions or tracks is more strongly associated with different factors of social cognition.

5.4.2 Conclusion

Altogether, the results from previous studies may be affected by confounding factors such as structural disconnectivity of the white matter networks necessary for social cognition functioning. The social cognition factors of the social cognition scores showed different associations with white matter networks; the SCC factor is supported by a right hemisphere network that comprised of association, commissural and U-shaped tracks that connected frontal central, temporal and limbic brain regions. The motivation factor formed more inferior network that depends on widely distributed brain regions of both hemispheres and comprised of association and U-shaped tracts that connected limbic regions with partial and frontal regions, while the interest in others' factor was linked to a projection track that connected the thalamus and the limbic regions to distributed area of the frontal lobe. However, the findings of this study suggest that identifying the quantitative damage to the white matter circuits can significantly predict the social cognition factors dysfunction among stroke survivors.

CHAPTER 6

SOCIO-COGNITIVE DEFICITS AFTER STROKE:

A CASE STUDY REPORT

Abstract

Focal brain injuries of specialised cognitive structures and processes can significantly impair one's socio-cognitive abilities and functioning. SC is a post stroke survivor, with large cortical and sub cortical lesions involving the left orbito-frontal cortex. Post stroke, SC presented with apparent problems in everyday social behaviour and involuntary swearing which were not apparent before the brain lesion. His cognitive and social cognition abilities were assessed using the SCS, BCoS and OCS. The results showed selective impaired social cognition domains related to mindreading and the ability to attribute mental states to others (SCC, motivation and mindreading) rather than openness and socializing with people (interest in others). These deficits co-occurred with SC having some language impairments and some deficits in verbal working memory, but also relatively good performance on tests of executive functioning. The results suggest that aspects of social cognition may dissociate from core cognitive processes and there may be impaired access to stored knowledge about social norms perhaps due to damage to fronto-temporal connections.

6.1 INTRODUCTION

Social cognition broadly refers to the outcome of the cognitive structures and processes influencing the interaction between individuals in social contexts. This includes, but is not limited to, how people think about other people, and how that in turn influences their feelings, behaviour, and social interactions. Following a brain injury, patients and carers often report changes in personality, emotional impairments, interaction with the environment, social reasoning and social behaviour. For instance, an individual may be unable to understand how their behaviour affects others, as they fail to read others' emotions and thinking (Callahan et al., 2011; De Achaval et al., 2010). As a result, the individual may show inadequate emotional feelings and expressions.

In addition, problems related to emotional processing, including impaired mood, emotion regulation and emotion perception, can detrimentally influence many aspects of patients' social interactions and participation in social networks (Scott et al., 2012). For example, apathy is a common problem after a stroke (Sagen et al. 2010; Mayo et al. 2009), whereby patients find difficulty starting any spontaneous activity such as starting or sharing a conversation (Lane-Brown & Tate, 2009). Conversely, some may become impulsive after stroke (Hainline, Devinsky & Reding, 1992), and this could affect their problem-solving and decision-making abilities, so they may tend to choose inappropriate options that often result in undesirable consequences (Scheffer, Monteiro & de Almeida, 2011). Social cognition has been found to mediate the link between neurocognition, as processes of linking and appraising information, and social functioning (Schmidt, Mueller & Roder, 2011), and this may determine stroke survivors' engagement to the rehabilitation plan and consequently the outcome of this process on reducing the impairments caused by stroke. Therefore, assessing the

cognitive and socio-cognitive abilities of individuals after stroke is important to estimate the impact of the damage on normal behaviour functioning and is essential for early intervention care planning.

Previous studies in social cognition have endeavoured to identify the impact of brain damage on executive functioning and the necessity of executive functioning for social cognition operations. Executive functions are a set of cognitive functions including, but not limited to, planning and working memory, that depend on distributed networks driven by the frontal lobe. However, some research have advocated for a division of executive processes into ‘cold’ logic-based EF and ‘hot’ emotional-based EF (see Ask & Granhag, 2007; Cavrak, 2010; Greene et al., 2001; Roiser et al., 2009). Executive functions have been found to be impaired post-stroke and traumatic brain injuries, and as a result of both focal and diffuse injuries (Cicerone et al., 2006; Goss, 2013; Samson, Houthuys & Humphreys, 2015). For example, in a meta-analysis study, Yang and Raine (2009), investigated 43 functional brain imaging studies that linked abnormalities of frontal lobe’ structure to antisocial, violent and psychopathic individuals. Their finding emphasis on the significant link between functional impairments in antisocial individuals, and the prefrontal structure, particularly in PFC, OFC, ACC and dPFC. Moreover, Cardoso, Branco, Cotrena, and Paz Fonseca (2015) studied, in a sample of patients with ischemic strokes, the interrelation between “cold” (logic-based) EF, using measures of cognitive flexibility and working memory, and “hot” (emotion-based) EF using the Iowa Gambling Task (IGT), which taps emotional decision making. They found no significant correlations in performance between the two sets of tests, suggesting some degree of independence between ‘cold’ and ‘hot’ executive processes.

In addition to its role in executive functioning (for a review see Fuster, 2001), there is also evidence to suggest that the OFC plays a key role in at least some aspects of social cognition (Kemp et al., 2013). Specifically, the OFC has been implicated in the processing of impulsivity (Toplak, Jain & Tannock, 2005), moral judgment (Mendez, 2009), emotional states attribution (Adolphs, 2002), emotional response to facial expressions of anger (Beyer, Münste, Göttlich & Krämer, 2015), self-related desire (Wang, Volkow, Telang et al., 2004), desire attribution (Kawadata & Zeki, 2008), reward related activity and motivation (Leotti & Delgado, 2011), attitudes (Cunningham, Haas & Jahn, 2011), social knowledge faux pas (Stone, Baron-Cohen & Knight, 1998), and apathy (Levy & Dubois, 2006).

Other studies have also suggest that patients with OFC damage can have problems in social cognition that can be unrelated to other cognitive deficits associated with frontal lobe function. For example, Roca et al. (2010) report that OFC patients fail on ‘faux pas’ tests of social interaction (judging whether a statement is appropriate or inappropriate according to the social context) but not necessarily on other tests of executive function. The authors suggested that the OFC may play a particular role in social decision making. More classically, patient such as Phineas Gage have been noted as having marked problems in social cognition after damage to the OFC (Haas, 2001) although his intellectual abilities were intact (Harlow, 1848, cited in, Kihlstrom, 2010).

Given the inconsistency regarding the tripad relationship of executive functioning, social cognition and OFC, there is a need for a better understanding of how the different aspects and factors of social cognition may interact with each other following damage to the OFC. Therefore, the current study aimed to assess both executive and socio-cognitive processes of a patient, SC, who suffered a large lesion involving the left OFC. Following damage to the left OFC, SC presented with

apparent problems in his everyday social behaviour, including involuntary swearing which was not apparent before the brain lesion. However, the swearing problem could be inferred due to either impaired representation or limited access to stored knowledge about social norms following damage to fronto-temporal damage (Humphreys & Ford, 2005). Our hypothesis states, if his social cognition performance was consistent over time and did not differ from what is expected from chance consistency, then the problem (the swearing) could be interpreted due to impaired access to knowledge, and if the assessment was inconsistent, then the problem results from impaired representation. Thus, this single-case study offers an opportunity to investigate how damage to the OFC impacts social cognitive abilities and whether these abilities are associated with executive functions in which the OFC is involved. The single-case study approach can also complement the group-based approach which is often limited by the heterogeneity of the lesions and their extent within the study sample.

Post stroke changes in social cognition have been investigated in the current thesis (Chapter 3) resulted in four factors of social cognition that were linked to possible different cognitive mechanisms (Chapter 4), and which can be quantitatively linked to damage to specific white matter circuits (Chapter 5) of networks subtending these factors. Social cognition abilities were assessed using the SCS, and executive processes using the standardized measures on The Oxford Cognitive Screen (OCS) and the Birmingham Cognitive Screen (BCoS) tests; Humphreys et al., 2012). The OCS was administered within few days post-stroke, and BCoS was administered six months post-stroke. The aim of this case-study is three folds: (1) To examine whether any deficits in social cognition are linked to impair executive processes; (2) whether SC's performance on the SCS is consistent over time, and (3) whether lesions of his white matter tracts can be associated with his performance on the SCS factors.

6.2 METHODS

Participants

Data were collected from 67 English-speaking healthy controls with ages ranging from 46-81. Participants were willing volunteers with no history of brain lesion who signed a consent form and were recruited from either (i) the School of Psychology, University of Birmingham, participant database, or (ii) The Cognitive Neuropsychology Centre, University of Oxford, or (iii) involved in public science activity such as Brain Awareness Week at the Science Museum - Oxford, and the Community Day - University of Birmingham. See **Table 6.1** for the demographics of the healthy controls.

Data were also collected for a single patient; SC. Patient SC is a 60 year-old right-handed white man with secondary school education and was formerly involved in computer sales. SC presented with apparent problems in his everyday social behaviour, including involuntary swearing which were not apparent before the stroke.

Table 6.1 Demographics of patient SC and healthy controls.

Demographics	Controls (N=67)	Patient SC
Gender (M/F)	(34/32)	Male
Age	65.7 ± 7.9	60
Education	N (%)	
Primary School	1 (1.5%)	
Secondary School	26 (38.8%)	Secondary school
College	8 (11.9%)	
Non-University Diploma	7 (10.7%)	
University degree	21 (31.3%)	

His processed CT scan lesion map indicated that the stroke caused a large damage (lesion volume= 22.30), mostly to the left frontal and temporal brain areas

including; frontal and temporal poles, central opercular, frontal medial, frontal operculum, frontal orbital, subcallosal and insular cortices, as affected various gyri including the heschl's, para cingulate, superior temporal, superior frontal, para hippocampal and middle frontal gyri (see Figure 6.1). Damage also extended to the white matter tracts, the quantitative data revealed damage including lesions in long association fibres connecting the frontal and temporal lobes; the uncinate, the posterior and long segments of the arcuate fasciculus, the inferior occipito-frontal fasciculus (IFOF), the cingulum, corpus callosum and all three segments of the superior longitudinal fasciculus (SLF). In addition to lesions on the U-shaped tracks running beneath the central sulcus from the parietal postcentral gyrus to the frontal precentral gyrus including lesions to the face and hand U-tracks ‘inferior, mid and superior segments’, as well as all the five branch of the insular tracks that connect the frontal lobe into the external capsule to reach the insula.

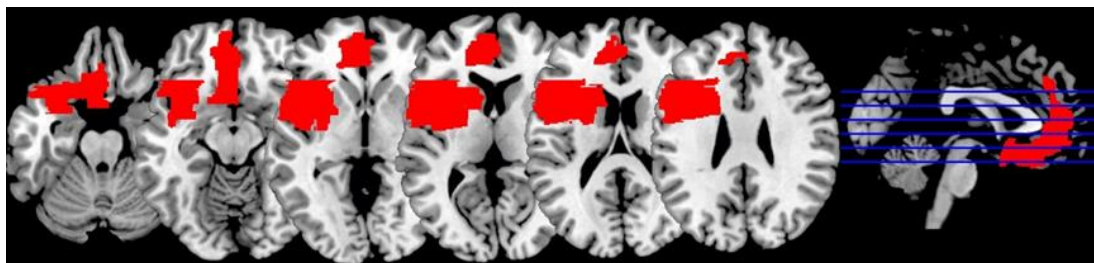


Figure 6.1 The VLSM analysis of SC's CT scan. The areas marked in red are detected as lesioned tissue when contrasted relative to 100 control scans using FWE $p < 0.05$.

Measures

Participants were assessed using the novel social cognition screen (SCS). It consists of 15 tests designed and adopted to be aphasia friendly (see **table 6.2** for the descriptive statistics of social cognition measures, and Appendix I for task descriptions) .

SC's cognitive competences were assessed using the OCS within few days after the stroke and six months later using the BCoS. The OCS has been designed to provide quick assessment for cognitive functions following brain injuries, which acts as an indicator to the affected abilities that will need further investigations (see **table 6.3** for the OCS description measures).

BCoS provides the norms and cut-off points for impaired abilities, with the tests being designed to be applicable to patients suffering from disorders such as aphasia and neglect. It consists of 28 tasks which assess five broad cognitive domains including attention and executive functions, language function, long term memory, number skills and praxis (see **table 6.4** for the descriptions of the BCoS measures). The SCS was administered to SC twice over six sessions, which took 10 months to complete. It is important to note that the time gap between the two screens was about two months, which minimizes practice or familiarity effects with the tasks or test items. Test instructions were repeated when necessary in order to best judge that SC understood the tasks. All the social cognition tasks were repeated in order to test for consistency of performance (cf. Warrington & Shallice, 1979).

6.3 RESULTS

6.3.1 Social cognition assessment

A single case vs. group calculator -Singlims_ES.exe (Crawford et al., 2010) was used to estimate the significance differences between SC's performance and that of the healthy control group. The performance of the healthy controls and SC on the social cognition measures is shown in **table 6.3** in **bold** are scores where SC performed outside of the control range (2 SD relative to the mean).

Table 6.2 Descriptive statistics of social cognition measures of the control participants.

Measures	Mean	SD	Minimum	Maximum
Go/No-go				
correct responses	8.08	1.25	4	9
false positive	16.64	2.40	6	18
RT (ms) correct action	2327.57	1038.71	702.17	1038.71
False belief	7.77	0.51	6	8
Intention	3.93	0.38	2	4
Moral reasoning	7.91	0.29	7	8
Emotion	8.10	1.07	6	10
Desire	6.82	0.46	5	7
Motivation	6.72	0.63	5	7
Attitudes				
high rate	8.32	1.50	0	10
low rate	2.74	2.08	0	10
Humour	4.53	0.73	2	5
Proverbs	8.55	1.13	6	10
Anger	3.86	3.33	0	13
Emotional Empathy	3.68	0.48	3	4
Cognitive Empathy	14.24	4.45	4	23
Apathy	29.27	5.24	20	43
Faux pas	57.89	3.14	48	60

Except four measures: go/no-go task, apathy, cognitive empathy and attitudes which SC fared well, he scored significantly worse than healthy controls on 11 out of 15 tests. The impaired functions included three out of the four SCS factors. Specifically, impairments were discerned in the social cognition control, motivation and mindreading factors, but not in the interest in others factor.

Item Consistency

Item consistency was assessed across the two test occasions for those assessments which contained four-answer alternatives (reading emotions, humour, desire), where the probability of generating a correct or incorrect answers by chance was less than in

the other assessments. For these analyses, SC's performance was compared with the levels of performance expected from his level of correct responses and assuming chance consistency across test sessions. The results showed that SC's performance across the two assessments did not differ from chance consistency on reading emotion ($\chi^2 = 1.53, p = 0.466$), desire ($\chi^2 < 1.0$), or humour ($\chi^2 < 1.0$).

Table 6.3 SC's performance compared to the mean performance of the control participants on the Social Cognition Screen

Measures		Controls*	SC **	T	P
Go/No-go	Go	16.64 ± 2.40	17	0.15	0.44
	No-go	8.08 ± 1.25	8.5	0.33	0.37
	RT	2327.57± 1038.71	2284.44	-0.04	0.48
False belief		7.91 ± 0.30	6	-6.096	0.000
Intention		4.00 ± 0.00	3	-9.574	0.000
Intention Control		3.96 ± 0.19	4	0.21	0.42
Moral reasoning		8.00 ± 0.00	7	-9.574	0.000
Emotion reading		8.44 ± 1.09	5	-3.062	0.003
Desire		6.70 ± 0.68	3	-5.188	0.000
Desire Control		6.94 ± 0.24	4.33	-10.71	0.00
Motivation		6.70 ± 0.68	3	-5.188	0.000
Motivation control		6.88 ± 0.55	4.67	-3.96	0.00
Attitudes (High rate)		8.52 ± 0.86	9.6	0.829	0.423
(Low rate)		3.58 ± 0.76	3.3	-0.355	0.728
Attitudes Control		8.48 ± 1.43	7.5	-0.68	0.25
Humour		4.88 ± 0.33	2	-8.481	0.000
Proverb		8.91 ± 0.80	6	-3.540	0.002
Anger		1.33 ± 1.37	17	10.989	0.000
Emotional Empathy		3.91 ± 0.30	3	-2.904	0.015
Cognitive Empathy		8.20 ± 3.38	10	0.514	0.615
Apathy		12.77± 2.32	13	0.925	0.096
Faux pas		56.18± 3.84	45	-2.795	0.018
Faux pas Control		58.84 ± 1.66	45	-8.25	0.00

* Only 27 of the 67 control participants completed the entire battery of the SCS.

**The table presents the mean performance of SC across the two test occasions

6.3.2 General Cognition Assessment

(a) *The Oxford Cognitive Screen (OCS)*

SC's cognitive ability was assessed 2 days post stroke using OCS and the results showed deficits on 7 out of 11 cognitive domains included in the OCS (see **table 6.4** for more detail). The assessment presented deficits in picture naming and semantics, sentence reading, number writing, recognition memory and spatial attention. The impairment in spatial attention was most dramatic.

Table 6.4 SC's scores on the OCS measures

Task Name	Measure	Cut off < 5%	SC
Picture Naming	Overall accuracy	3	1
Semantics	Overall accuracy	3	2
Orientation	Overall accuracy	4	6
Visual Field	Overall accuracy	4	4
Sentences Reading	Overall accuracy	14	0
Number Writing	Overall accuracy	3	2
Calculation	Overall accuracy	3	4
Broken Hearts	Overall accuracy	42	9
	Space Asym (left inattention >0, right <0)	-2	-8
	Obj Asym (left inattention >0, right <0)	0	0
Imitation	Overall accuracy	8	11
Recall & Recognition	Verbal Memo Recall Recognition	3	2
Executive Task	Circles	5.95	6
	Triangles	5	6
	Mixed	4	8

(b) *The Birmingham Cognitive Screen (BCoS)*

Nine months post-stroke SC's cognitive abilities were assessed using the BCoS which provides more detailed screening than the OCS (see **Table 6.5** for the tests and SC's performance). SC was substantially impaired on the tests of auditory attention (covering working memory, rejection of related distractors and sustained attention). There were also deficits in picture naming and in verbal recall and reading (sentences, non-words, numbers) plus also a slight deficit in figure copying.

Table 6.5 SC's scores on the BCoS measures.

Cognitive Domain	Task	Cut off points ≤64 yr	SC
ATTENTION	Apple cancellation - total	42	50
Spatial	Apple asymmetry - full	<-2 or >2	0
	Apple asymmetry – incomplete	<-1 or >1	0
	Left visual neglect	4	4
	Right visual neglect	4	4
	Left visual bilateral	8	8
	Right visual bilateral	8	8
	Left tactile neglect	4	4
	Right tactile neglect	4	4
	Left tactile bilateral	7	8
	Right tactile bilateral	8	8
Controlled	Auditory - WM 1 - practice	>1	3
	Auditory - WM 1 - recall	3	1
	Auditory - accuracy	51	0
	Auditory – sustained attention	>1	0
	B'ham – accuracy	Accuracy <6	10
	& rule	Rule <1	2
LANGUAGE			
spoken	Instruction comprehension	3	3
	picture naming	11	13
	sentence construction	8	8
writing	Nonwords - accuracy	5	6
	Nonwords - time	>14 sec	10
	Sentences - accuracy	42	40
	Sentence - time	23 sec	25
	Words + nonwords	3	3
Long Term Memory			
orientation	Personal	8	7
	Time and space (MC)	6	6
episodic	Story – free call 1	6	0†
	Story – recognition 1	13	15
	Story – free call 2	8	0†
	Story – recognition 2	13	13
	Story – decay	>1	2
	Task – recognition	9	9
NUMBER			
reading	Total	8	4
writing	Total	5	5
calculation	Total	2	2
PRAXIS			
	Figure copy	42	38
	Multi – step object use	11	12
	Gesture production	10	12
	Gesture recognition	5	3
	Imitation	9	12

†Poor performance due to aphasia

6.4 DISCUSSION

SC, a patient with left hemisphere damage to the OFC and temporal lobe, had selective impairments in cognition as well as a range of deficits in three of the four factors of the social cognition screen, namely, the social cognition control factor, the motivation factor, and the mindreading factor. On his first standardised tests of cognition (OCS), SC showed impaired performance on tasks tapping the attention domain (spatial attention: egocentric and allocentric neglect), verbal memory (recall and recognition), as well deficits in the language domain including reading, access to semantic/ conceptual knowledge about objects, word finding and number writing.

On second cognitive assessment (BCoS), SC generally fared well especially on tasks tapping spatial attention but had sustained selective deficits on the auditory attention task from the BCoS (tapping selective attention, working memory and sustained attention), various reading tasks (reading sentences, non-words and numbers). There was also a small deficit on figure copy. SC's memory deficit was more apparent on recall than recognition and this, along with the poor reading performance, may reflect poor internal speech (Hinke et al., 1993). The noteworthy that SC's poor performance on the auditory attention task, however, is less easy to attribute since this task primarily depends on maintaining items in working memory using them for target selection. Strikingly, SC performed well on the executive tests (tringles and circles trails in the OCS and rule finding and switching in the BCoS) in both the initial and follow-up assessments. He also fared well on go/no-go task from the SCS assessing inhibition.

The generally good profile for cognitive performance (barring tests dependent on internal verbal representations i.e. auditory controlled attention) contrasts with SC's scores on the tests of social cognition. As stated above, SC impaired social

competences were apparent in three of the SCS factors: The social cognition control factor, the motivation factor and the mindreading factor. The social cognition factor reflects multiple features merging between logical and emotional aspect of cognition. On the one hand, it involves elements of social cognition such as reading emotions, false belief, proverb interpretation and humour linked to higher cognition abilities including visual attention, inhibition, memory and academic level (See chapter 4, and Ahmed & Miller, 2011; Kiang et al., 2007; Uekermann et al., 2008). On other hand, it assesses representations and variables affected by emotional appraisal such as anger and faux pas. SC's deficits on this factor are unlikely to reflect poor language abilities, as even though he suffers from aphasia, patients with even worse language abilities were able to pass tests of social cognition including first and second order false belief (Apperly et al., 2006). The deficits are also unlikely to reflect impairments in EF, given the SC performed well at the executive tasks in the screening tests.

One other interesting aspect of SC's performance is the consistency of the deficit over time. SC exhibited impaired performance in two intervals of the SCS assessment, and this means that his performance did not differ from what is expected from chance consistency, this suggests that SC's impairment can be attributed to poor access to any learned representations (Humphreys & Ford, 2005; Warrington & Shallice, 1979), rather than impairment in the representation itself.

It should also be noted that on the attributing others desire and motivations tasks of the SCS, SC failed not only the experimental task but also the control task. In these cases, it seems likely that the cognitive load on working memory may have been too great for him to make judgements to the control as well as the experimental stimuli. In such instance it is hard to deduce whether there is a problem in social cognition. It

would be useful to test this in follow-up examinations where the load on working memory is reduced.

Taken together, these results concur with findings showing impaired social cognition, but spared cognitive and executive function abilities following damage to the frontal lobe. This is similar to the profile of Phineas Gage whose damaged to the OFC was linked to marked problems in social cognition (Haas, 2001), but intact intellectual abilities (Harlow, 1848, cited in, Kihlstrom, 2010). This is also consistent with findings from patients with variant frontotemporal dementia (Lough, Gregory & Hodges, 2001) whose poor theory of mind performance was independent from their relatively intact executive functioning. Yet, one might say that the swearing problem present in SC could be related to cognitive dysfunction verbal working memory and controlled attention (see Chapter 4).

In considering SC's lesion map (see Figure 6.1), it is clear that a large number of left hemisphere tracks were affected. Of these tracks, I note damage to the three segments of the superior longitudinal fasciculus (SLF) and the fronto-insular tracks. Within these bundles, the results from Chapter 5 suggest that the integrity of the left SLF, segment 1 (SLF1) and the left fifth fronto-insular tracks can influence performance on the motivation factor of the SCS. This result underscores the importance of single-case studies as they can provide convergence evidence pertaining to the association of specific tracks with functioning in a particular domain.

However, it is important to acknowledge the reverse where many of the lesioned tracks in SC did not emerge as significant predictors of performance on the SCS factors (see Chapter 5). It might be speculated that group analyses may lead to erroneous assumption about the extent of the networks subtending social cognitive functioning. The case of SC suggests that damage to left hemisphere tracks can lead

to decrement in performance, and thus it emphasizes the potential role of both hemispheres in social cognition. Alternatively, the group analysis in Chapter 5 may simply indicate greater predictive power for right hemisphere tracks compared to left hemisphere tracks, which is plausible given evidence assigning greater importance to structures associated with social conduct, decision-making and emotional processing within the right compared to the left hemisphere (Tranel et al., 2002). Future research will be able to address this question by comparing left versus right hemisphere damage on social cognition.

In addition, SC lesion profile shows damage within the anterior temporal cortex. In this regard, SC's frontal and temporal sub-cortical regions were largely affected, especially the Uncinate Arcuate Fasciculus that connects anterior temporal lobe with the orbital and medial prefrontal cortex (Schmahmann & Pandya, 2007). As lesion volume exceeding 50% suggests tract disconnection (Chechlacz et al., 2015; Thiebaut de Schotten et al., 2014), the lesion volume of this track in SC (lesion volume = 0.675) is most likely disconnected. In light of the role of the anterior temporal cortex in representations of social norms (Zahn et al., 2008), this temporal damage may have reduced SC's sensitivity on the normative rules about moral behaviour, faux pas statements.

6.5 CONCLUSION

Taken together, these results suggest that SC has impairment in social cognition. There was some selectivity in this deficit, with aspects involve attribution, social norms and knowledge more than aspects related to social interaction. These deficits co-occurred with SC having aphasia and some deficits in verbal working memory, but

also relatively good performance on tests of EF including inhibition control. The results suggest that aspects of social cognition may dissociate from core cognitive processes, and that social cognition impairment may be associated with limited access to stored knowledge about social norms following damage to fronto-temporal damage (Humphreys & Ford, 2005).

CHAPTER 7

GENERAL DISCUSSION

Synopsis

As stated in the thesis, social cognition is a multi-dimensional function with possible multiple cognitive processes supported by white matter tracks connecting brain areas the underpin specific component of social cognition. As evident from the findings presented in the various chapters, social cognition is susceptible to brain abnormalities and injury due to stroke. A key goal of the current thesis was to validate the utility of a social screen that is both comprehensive and efficient. The study also offered an opportunity to ask key question that pertains to the neurobiological underpinning of social cognition. Specifically, it offered insight into whether (1) specific anatomical lesion predicts the patients' performance on the social cognition; and (2) there are, aside from higher cognition, other indicators of social cognition impairments following stroke. In the following section, I summarize the thesis key findings, its implications, and future direction for research.

7.1 SUMMARY OF CHAPTERES

Chapter 2: The Social Cognition Screen

Building on previous literature, reviewed in Chapter 1, the goal of Chapter 2 was to develop a social cognition screen to specifically, address social cognition difficulties arising from brain injuries. To the best of my knowledge, there are no psychometric instruments that provide a comprehensive profile of social cognition deficits in this population. Moreover, it aimed to design and improve tasks that capture the multidimensionality of social cognition processes and overcome the limitations of previous scales by formulating clear definition of the variables, validating and standardizing the tasks, and to ensure that are suited for use in brain-damaged individuals. The measures of the social cognition screen (SCS) were designed to address a wide range of social cognition phenomena necessary for everyday social interactions that they tap common problems in post-stroke patients and importantly sensitive to inter-individual differences. The final version of the SCS comprised of 15 tasks and measures assessing: impulsivity, apathy, anger, attribution others false belief, emotion states, intention, desire, motivation, moral reasoning and psychological attitudes, in addition to faux pas, cognitive and emotional empathy, humour and figurative language. The screen includes newly created assessments for many of the abilities noted above. This test battery takes approximately one hour to complete, and can be applied for diagnostic and research purposes, and a description of the SCS tasks and measures was provided.

The procedures for assessment and extracting the psychometric features of the SCS, led to results ranging between adequate to excellent findings. The application on healthy control sample aims were (i) to evaluate the newly designed tasks in terms of their suitability, sensitivity and clarity for later implementation on the clinical sample,

and also (ii) to develop a frame of reference and norms to enable comparisons and determine the diagnostic differences. During data collection from healthy controls, modifications were made to improve some measures to fit the aspired objectives such as time efficiency and clarity. Inter-group comparisons revealed no significant differences between healthy control participants based on gender and the level of education, however, the age groups comparisons revealed significant differences between age groups on humour task. Therefore, age norms were developed, and the cut off scores for each measure was determined. The clinical group application included further goal beside the assessment; to develop the psychometric properties of the screen. The reliability studies including internal consistency and stability over time; the internal consistency for the SCS maintained acceptable level ($\alpha = 0.7$), and the stability over time with duration between the test and the retest intervals ranging from 4 to 22 weeks, showed no significant differences between the intervals indicating reliable properties of all the measures. The results of the study convergent validity of the new tests in relation to other standard tests in the literature, all correlations were significant at $p < 0.01$, except the go no go task $p < 0.05$, and the correlations ranged between adequate (0.57) to strong (0.96) coefficients, which suggests that the SCS tasks have a measurable association with standard measures.

Chapter 3: The Domain Structure of Post-stroke Deficits in Social Cognition

This chapter aim was to identify the social cognitive behavioural and neurological syndromes caused by stroke, that reflect impaired functions including changes in personality, mood, thinking and social behaviour. The aim of this chapter was to describe the association linking different social cognition aspects together through analysing the cross-subject deficits. For this objective, a data reduction method was employed using *factor analysis*. Factor analysis helps identifying

common features of the variables by capturing the correlation of behaviour scores across subjects, to reveal the core of underlying behavioural dimensions. The model produced for the SCS comprised of four factors that explained the majority of the total variance.

The first factor, ‘Social Cognition Control’ (SCC), loaded with the impulsivity assessment of go/no-go task which accounts for inhibition control ability along with seven other variables, and thus encompassing almost half of the tasks. These tasks were the false belief, faux pas, and anger, reading emotions, moral reasoning, humour and figurative language tasks. This factor explained the largest proportion, and accounted for one third of the behavioural variance, and on which most of the patients (23 out of 26) were impaired. It is noteworthy that the loading along with the go/no-go task may suggest that social cognition variables may be affected by cognitive impairments, reflecting possibly the contribution of executive load on performance (Fino et al., 2014). Indeed, this is to be expected given that, clinically, post-stroke socio-cognition deficits tend to be dominated by cognitive impairments.

The second factor, ‘Motivation’, comprised two variables: desire and motivation. This factor represents processing and understanding of the motivation underlying behaviour. Interestingly, desire overlapped with motivation rather than intention, which may suggest that identifying others’ desire is linked to the drive underlying the goal-directed behaviour rather than a strategy undertaken to satisfy that desire (intention) which may not be consistent with the desire.

The third factor, ‘Interest in Others’ (IO) loaded on three measures: cognitive empathy, apathy and psychological attitudes. The variables in this dual dimension factor are characterised with the social tendency to interact with others, as it would characterise social behaviour. It is interesting that apathy loaded on this factor and on

the factor linking desire and motivation reasoning. Apparently, understanding motivation in others (factor 2) may be distinct from being motivated (factor 3). Finally, factor 4, 'mindreading', loaded on two measures: understanding others' intention and emotional empathy. Both variables may involve selective processes implicated in forming predictions about how others may feel in a given context.

The structure of this analysis factor analysis did not comply with the theoretical notion assuming social cognition as a unitary function (ToM), nor with the purported dual division of the cognitive and affective domains of ToM. This structure exhibited a relationship that could be more interpreted in terms of their dependency on general cognitive abilities rather than operating independently. The analysis investigating the association between factors showed only one significant correlation between the SCC and motivation factors which may indicate that processing motivation is partly dependent on general cognitive abilities, at least in part through the association of the SCC with inhibitory control.

A comparison between the between the patients and controls showed significant differences on 3 factors, namely: social cognitive control, interest in others and mindreading. This confirms that the stimuli used to assess each component were sensitive to detect impaired performance. It is important to note that while there was selective sparing of motivational abilities, it is evident that understanding of others' desires and motivations alone is not sufficient to function properly in a complex social situation. Nonetheless, motivation appears as an independent domain that is more resistance to brain damage following stroke.

Chapter 4: The Cognitive Implications for Social Cognition Deficits after Stroke

The aim of chapter four was to investigate the associations and dissociations between social cognition domain deficits and ‘general cognitive’ deficits. Given that in the previous chapter (Chapter 3), the first loading factor reflected poor executive control, I tried to answer the question to what extent impairments in ‘general cognitive’ processes including memory, language, praxis and executive function can impact on social cognition performance.

Patients’ scores on SCS and the BCoS were combined and analysed using factor analysis. The final rotated model produced seven factors that accounted for 78% of the total variance in the patients’ performance. The factors produced showed consistent variable overlap with clusters of the SCS, indicating common patterns of deficits across many stroke survivors. Only two measures overlapped with episodic memory (recognition and decay) and spatial attention from the BCoS. These results are interesting as they indicate largely independent processing of the social cognition dimensions, and that are consistent with previous evidence of such dissociations in a meta-analysis covering 52 studies of patients with schizophrenia (Fett et al., 2011).

The first factor, ‘Social Rules’, loaded with social cognition components including motivation, desire, anger and faux pas, reflecting the abilities pertaining to understanding others’ basic drives and motivation. These abilities may constitute mechanisms that stroke survivors may resort to in order to understand social rules and to employ them in their social interactions.

The second factor, ‘Impulsivity’, consisted of three measures included impulsivity, figurative language, and false belief. The loading of the Go/no-go task onto this factor may reflect the contribution of executive load on performance, which

may result in tendency to leap to conclusions rather than analysing the facts and details of the social situation. Factor 3, labelled ‘Sequencing Behaviour’, consisted of two measures from the BCoS, namely rule-finding accuracy and multi-object use. Factor 4, labelled ‘Social Memory’, combined two measures from the SCS and three measures from the BCoS. The factor loadings consisted of episodic memory, spatial attention, story decay, episodic memory and finally humour and emotion recognition from the SCS. Factor 5, labelled ‘Social Behaviour’, included measures of social cognition components and independent of the cognitive factors. The factor consisted of cognitive empathy, apathy, moral reasoning and psychological attitudes recognition, and thus it may reflect one’s social tendency toward social interactions. Interestingly, variables of this factor reloaded together as in the previous principal component analysis confirming the interaction between these variables and representing a stable domain of social cognition. Factor 6, labelled ‘Verbal Attention’, consisted of two measures from the BCoS assessing language (picture naming) involved approaching the conceptual knowledge of the object and name retrieval and controlled attention (auditory attention accuracy). This factor relies on language abilities as the stimuli for the attention task consisted of set of words, and assesses sustained attention, selective attention and working memory. Finally factor 7, labelled ‘Mindreading’ included two measures from the SCS, namely intention recognition and emotional empathy. These measures reflect one’s ability to speculate about others’ intentions by analysing the facts of the current social context and the associated mental states believed to represent the observed action (automatic process) rather than more complex demands such as memory, EF (controlled process).

The results of regression analysis confirmed inhibitory control is necessary for succeeding on understanding others’ belief and also to comprehend the figurative

language. After brain injuries, education appears to play a protective role for emotion recognition, years of education was the best predictor of reading emotions, followed by spatial attention.

Chapter 5: Social Cognition Domain Deficits: Exploring Connectional Anatomical Relationships

The main aim of this chapter was to explore the possible link between localising the anatomical regions critical across multiple social cognition and cognitive domains. I tried to find out how much of the variance in social cognition can be explained by anatomical damage, and to what extent damaged neural circuits can predict impaired social cognition function. A track-wise lesion-deficits analysis approach was used. This approach relies on describing the disconnection caused by lesion at individual level. The linear regression analysis revealed several significant models, relating nine white matter tracks to three of the SCS factors suggesting that processing social cognition factors likely rely on specific white matter tracks of networks involved in the processing of social cognition functions.

First, a right hemisphere network consisting of the Fornix, the Hand superior track and the Cingulum posterior segment predicted the performance on the SCC factor. Second, a rather distributed network containing fibre bundles of both hemispheres predicted performance of the motivation factor. These included the left and right bundles of the first branch of the Superior Longitudinal Fasciculus (SLF) and the right bundles of the second and third segments of the SLF, the left branch of the Inferior Longitudinal Fasciculus (ILF), and the left branch of the fifth bundle of the Fronto-Insular tract. Finally, the right segment of the Anterior Thalamic Radiation (ATR) track predicted the performance of the Interest in Others factor. All together, these results bring insight to the distributed brain regions identified in the literature as mechanisms

involved in in purportedly separate social cognition processes, are in fact structurally connected to support a specific domain function.

Chapter 6: Socio-Cognitive Deficits after Stroke: A Case Study Report

The significance of white matter pathways subtending the SCS factors was examined in a single case study of a stroke survivor with left hemisphere lesions to frontal and temporal areas. Following stroke, SC presented with apparent problems in everyday social behaviour and involuntary swearing which were not apparent before the brain lesion. This study aimed to assess possible reason of his exhibited problem and also to uncover potential convergence evidence pertaining to the association of specific tracks with functioning in a particular domain. SC is a stroke survivor, with large cortical and sub cortical lesions to the left hemisphere involving areas in the frontal and temporal lobes and left orbito-frontal cortex. His cognitive and social cognition abilities were assessed using the SCS, BCoS and OCS. The results showed selective impaired social cognition domains related to the ability to attribute mental states to others (SCC, motivation and mindreading) rather than openness and socializing with people (interest in others). These deficits co-occurred with SC having some language impairments and some deficits in verbal working memory, but also relatively good performance on tests of the executive functions. The results suggest that aspects of social cognition may dissociate from core cognitive processes and there may be impaired access to stored knowledge about social norms perhaps due to damage to fronto-temporal connections.

The results from the track-wise lesion-deficit analysis conducted on the clinical group in Chapter 5 suggested the involvement of the left first segment of the SLF and the 5th insular track in the functioning of abilities subsumed in the motivation factor. As the patient's lesions were limited to the left side, we can say with greater degree of

confidence that they these tracts are associated with performance on the motivation factor of the SCS. This convergence of evidence from the group and the single-case studies underscores their combined contribution to ascertaining the association of specific tracts with functioning in a particular domain.

7.2 GENERAL DISCUSSION

Previous research's studying psychosocial phenomena tried to investigate whether social cognition is a monolithic function that operate as a part of general ability or governed by more than one system. Currently, the main trend between researchers is directed toward a division based on the functions to cognitive and affective aspects of social cognition. However, studies that relied on single or few variables to assess social cognition reached contradictory results (e.g. Ahmed & Miller, 2011; Muller et al., 2010), and some affective aspect of social cognition have frequently been associated with general cognitive domains such as emotion recognition (Baker, Peterson, Pulos & Kirkland, 2014), and desire attribution (Fizke, Barthel, Peters & Rakoczy, 2014). Furthermore, anatomical regions linked to processing of key social cognitive abilities such as theory of mind found to be dissimilar (see: Schurz, Radua, Aichhorn, Richlan, & Perner, 2014, in a meta-analysis of functional brain imaging studies), probably driven by the use of for diverse tasks and stimuli.

More insight on social cognition operations can be provided using data reduction methods such as factor analysis. Factor analysis regroups variables into a limited set of clusters based on shared variance, so that relationships and patterns can be easily interpreted and understood (Yong & Pearce, 2013). Using factor analysis on data of

patients with brain lesions could provide a unique window into impaired factors' relationship with brain regions, and general cognitive functions decisive to a specific operation underlying the factor. This approach could refine our understanding of the relationship between brain anatomy and function.

The findings of the current investigations suggest that social cognition is an outcome of a rather multiple interdependent capabilities. The factor analysis of data collected from post-stroke survivors with the social cognition screen (SCS) produced a unique structure that did not comply with the theoretical notion assuming a unitary function (ToM), nor a dual division to cognitive and affective domains. The underlying four factors of the SCS that govern the production of social cognition are as follows: (1) The Social cognition control (SCC): the factor's main feature is *control* indicating that social competences depend on domain general abilities; (2) Motivation: an automatic process involving analysing the preference, advantages and motivations underlying others behaviour; (3) Interest in Others (IO): a factor that underlies the *socialisation* function and describes social behaviour and tendency for interacting with others, and lastly (4) Mindreading: a process that might involve automatically speculating about others behaviour using social schema, where one might speculate about others' intentions as in what others will do next in a sequenced context, or about how others will feel (emotional empathy) based on a sequenced behaviour in a given context. Notably, the IO and mindreading factors are independent and did not associate with other factors which suggest that their operation maybe subjected to selectivity.

The dissociation between SCC and mindreading factors, although both require speculating about others' cognitive states (false belief and intention), perhaps can be interpreted due to different underlying processes (Tager-Flusberg, 2001). Intention

attribution requires speculation about others' mental states believed to represent the immediate observed action (automatic process) and follows the logic sequence of the observed behaviour, while false belief is a more controlled process requiring more complex demands such as working memory and inhibitory control. It requires the ability to distinguish between a known fact and to give an explanation of a behaviour that conflicts with the observed known fact.

The dissociation between the factors suggests their independency, possibly reflecting natural variation in people's social cognitive abilities, and more broadly how their perception world map onto their individual belief and attitudes. For instance, although patient SC (Chapter 6) was impaired in SCC, motivation and mindreading, but nonetheless held positive attitudes towards others that did not affect his interest in social interactions and being around others.

More in-depth investigation regarding the relationships between social cognition aspects and general cognitive domain resulted in linking only two domain general functions (episodic memory and spatial attention) from the BCoS with social cognition. These results are interesting as they indicate largely independent processing of the social cognition dimensions. However, the patients' high rate failure on the SCC factor (23 out of 26) may point out that abilities required for faux pas, anger and moral reasoning—that loaded along with other social cognition aspects in this analysis—may not require direct specific general cognitive ability in order to operate normally.

The results of regression analysis confirmed that inhibitory control is necessary for understanding others' belief and also to comprehend the indirect social meanings conveyed in the figurative language. Interestingly, the proverb task, tapping figurative language ability, loaded with false belief rather than the language domain or episodic

memory. This may suggest that the social knowledge implicit in this task and similarly in false belief understanding is associated with inhibition control functions that may explain the patients' tendency to jump to conclusions rather than analysing the facts and details from the social context.

Moreover, the track-wise lesion-deficits analysis confirmed the significance of the role of white matter bundles connecting brain regions involved social cognition processes. The analysis revealed that specific white matter bundles were uniquely associated with three factors of the SCS, which suggest a potential of further type of validity in clinical neuropsychological research classically known as validity by systematic-empirical investigations (Franzen, 2000), which adds another credit to the SCS as a diagnostic assessment tool. Franzen (2000) explains that "validity in clinical neuropsychological research involved either the demonstration that scores derived from a test can accurately separate neurologically impaired individuals from unimpaired individuals or the demonstration of a statistical relationship between scores on a neuropsychological test and the result of a medical neuro-diagnostic procedure such as CT scan" (ibid, p.27). The SCS accomplished both goals; sensitivity in distinguishing impaired individuals on certain factors and associating their deficits with lesions to specific white matter networks that connect brain mechanisms together. However, the fourth factor, 'mindreading', which explained the least variance, was not associated with any of the hypothesised white matter tracks.

The distinction between neural networks for operating different factors increases the importance of the current findings, and potentially offers an explanation for the engagement of some brain regions (e.g. OFC, PFC, STS, TPJ) in processing functions reflected in all the four factors. However, the precise and extent of the contribution of these regions seems to differ in relation to each of the factors. The neural connections

associated with the SCC factor consisted of the hand superior U tract , adjoining the paracentral U tract and runs beneath the central sulcus from the postcentral gyrus to the frontal precentral gyrus (Rojkova et al., 2016), and the fornix and the cingulum tracks which are subcortical central regions. The motivation factor is dominated by connections mostly belonging to the ventral and temporal parts of the brain, including all the branches of Superior Longitudinal Fasciculus (SLF); more ventrally the second segment of SLFII that connects the angular gyrus to the posterior regions of the middle frontal gyrus (Rojkova et al., 2016); the Inferior Longitudinal Fasciculus (ILF) that connects the temporal and occipital lobes (Catani et al., 2003); and the fifth bundle of the Fronto-Insular track that connects sub-central gyrus to the posterior insula (Catani et al., 2012). Lastly, the anterior thalamic radiation (ART) is more likely to be the main white matter pathway for associated with IO factor. The ART projections pass through the anterior limb of the internal capsule and project on the whole surface of the frontal lobe and found to be more dominated to the anterior limb and frontal lobes, as the projections showed a reduced probability for the ventral portion of the precentral gyrus (Rojkova et al., 2016).

Converging evidence pertaining to the association of specific white matter tracks with functioning in particular social cognition domain was attained from the single case study (Chapter 6). The results pointed to the association of the left SLF I and the 5th frontal insular tracks with motivation factor. This result underscores the importance of the single-case study as it confirmed social cognition syndromes relationship with some connections collaborated in left hemispheres. They may also suggest that damage to left hemisphere tracks can lead to decrement in performance, and thus the potential role of both hemispheres in social cognition. Alternatively, the group analysis may simply indicate greater predictive power for right hemisphere tracks

compared to left hemisphere tracks, which is plausible given evidence assigning greater importance to structures associated with social conduct, decision-making and emotional processing within the right compared to the left hemisphere (Tranel, Bechara & Denburg, 2002). Overall, these findings underscore the importance of the single-case study as it confirmed the contribution or role of specific connections in left hemispheres to social cognition.

(a) What have we learned?

The results of the current thesis may further elucidate the relationship between social cognition, general cognitive domains, structural connectivity and the integrity of white matter pathways. Post-stroke social cognition deficits are a common difficulty affecting the majority of stroke survivors' everyday life, and can have great consequences on the patients' clinical rehabilitation process. Therefore it is recommended that patients' social cognition need to be assessed after the incidents routinely.

As social cognition consists of a set of social competences, there is a need to employ a battery that can capture the diversity of these competences and their underlying processes. As pointed out, these competences cluster into four factors. In this context, three aspects are worth noting: (1) some aspects of social cognition may dissociate from core cognitive processes. Therefore, an assessment of the patient's general cognitive profile may not be an adequate substituted for social cognition assessment, albeit it can act as an indicator of impulsivity, and potential difficulties in attributing belief and emotion states to others and misunderstanding figurative language and humour; (2) the dissociation between the interest in others (IO) factor, which represents social behavior, with the other three factors of SCS that encompass inferring others mental and emotional states as well as knowledge of social norms and

rules, may indicate that IO factor is governed by a self-regulatory mechanism that do not operate unless they are activated and it is an example of 'many processes by which moral reactions can be disengaged from inhumane conduct' (Bandura, 1986; 1988c as cited in Bandura, 1989, p. 54) ; and (3) the extent of the resistance of these factors to brain damage differs, with the motivation factor being most resistant and the SCC is most fragile.

Moreover, while damage of particular white matter pathways may indicate the presence of impairment in a specific aspect of social cognition, the distributed nature of these tracks in both hemispheres (e.g. the association of both left and right bundles of the SLF1 motivation) raises the possibility that affected functions are potentially recoverable by stimulating contra-lateral bundles, or regions they connect.

(b) The implications of the findings to the fields of social cognition and neuropsychology

The findings of this study have a number of important implications for future practice. Given the grave consequences of stroke on socio-cognitive abilities, social cognition is undoubtedly an important target for intervention and treatment in stroke patients. There is a crucial need for a routine assessment of these abilities as they may enhance the success of the rehabilitation process and reduce the patients' disabilities. The success of the rehabilitation process can ease the burden on the individual, and the caregivers, and reduce the economic costs afforded by societies, and loss of productivity. The brevity and comprehensive nature of the screen has practical application as it allows for a relatively quick and thorough assessment of social cognition factors, which could then provide further guide to the patient's rehabilitation plan. It also can be a valuable research tool of social cognitive functioning in stroke-survivors and particularly for research with a longitudinal

design. Future studies may address the possibility of creating a shorter and computerised version of the screen that could further facilitates the assessment and reduce the burden on patient. This is important area of research as routine assessments are often curtailed by the patient's short attention span, fatigue, and lack of physical movement following the stroke.

The current findings add to a growing body of literature on neuropsychology, integrating the information of social cognition assessment and mental operations with the white matter topography of stroke. The damage caused by stroke is largely affecting subcortical regions. Presenting models of subcortical white matter damage and cognition is substantial for better understanding this disease (Corbetta et al., 2015).

7.3 STRENGTHS AND LIMITATIONS

The current thesis provides novel additions to the existing psychometric and neuropsychological studies of social cognition. Presenting a psychometric instrument that inclusive, informative and sensitive to abnormalities in multiple domains of social cognition, provide a valuable tool for a comprehensive profiling of the patient's social cognitive abilities. The validation of the social cognition screen and standardization with cut off scores that complies with age norms performance are important features that substantiate its use in clinical settings. In addition, the screen includes two novel assessments (with matched control tasks): attributing motivation and psychological attitudes to others. These assessments are important given that impairments in this domain can be important to recognise when tailoring individual rehabilitation plans.

In the field of socio-cognitive neuroscience, using a data reduction approach has been less evident and the vast majority of studies examined performance at the level

of individual tests. In the light of the current findings, social cognition domains, determined by component analysis, provide a gateway for a better understanding of the operations and functions that directly and affect our social behaviour.

Another novel contribution of this thesis is the findings of the track-wise lesion-deficit analysis. This analysis revealed the role of unique white matter pathways in processing specific social cognition factors. These findings suggest that the distributed brain regions identified in the literature as mechanisms for these factors are in fact involved in various social cognition aspects. This is evident by the structural connections these pathways make between various brain regions that are involved in several socio-cognitive functions. This study also emphasised that selected brain regions and the white matter pathways that connect them together and contribute to the operation of both domain general and domain-specific functions.

A main limitation in this study is the sample size. Large sample sizes within this population can be challenging mainly due to two reasons: the participants and the prolonged testing. The participants were volunteers' patients and many would stop attending the sessions for various reasons such as moving to care home, having another episode of stroke, and fatigue. Naturally, the production and validation of the screen requires extensive and prolonged testing. While efforts were made to accommodate the patients, dropouts were inevitable. However, there is need to replicate this study with a larger sample to further confirm the validity and reliability of the screen. A bigger sample is also necessary to ascertain the findings from lesion-symptom mapping study, and which will further allow for a more detailed investigation into which particular sub-regions are important for the functioning of each the social cognition factors.

7.4 CONCLUSION

What we know about social cognition is largely based upon empirical studies that investigated how we internalize social cognition knowledge and skills and how we incorporate these competences in successful social interaction. This thesis aimed to advance our knowledge of social cognition deficits by investigating stroke patients. It also aimed to produce a practical and comprehensive screen of social cognition function, which is often impaired following stroke. The social cognition screen can be a resource to both research and clinicians in that it can be used to determine the impaired functions, and further our understanding of the neural correlates of specific socio-cognitive domains. More importantly, the comprehensiveness and the efficiency of the screen can improve the tailoring of the rehabilitation process and overall care for this patient population.

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Appendix I

Appendix I-1: False Belief and Moral Reasoning Task

1- A father holding a baby together with the mother who is pushing a pram are shopping; the father enters the shop and the mother is still outside looking at the vitrine, she puts her handbag inside the pram and continue looking at the dresses in the vitrine. Here I stop and ask the participant, “Can you tell me what is in the pram now?” – a “reality question”. After answering I ask, “where is the baby now?” – a “working memory question”.



1- Father with the baby go into the shop, mother leaves her bag inside the pram: what’s in the pram (Reality question), where is the baby? (Memory question)

2- I continue running the task, while the woman is busy watching the pram moving towards the street. The mother is still looking at the vitrine, unaware of pram. An old lady appears in the scene; she sees the moving pram and she runs after the pram. Here I stop the scene and ask, “what does the old lady think is in the pram?” – a “first order false belief” question. In order to assess ‘descriptive morality’ (Mendez, 2009), I ask a moral judgment question “from a moral point of view, how do you classify the old lady’s action, is it good, acceptable or bad?”



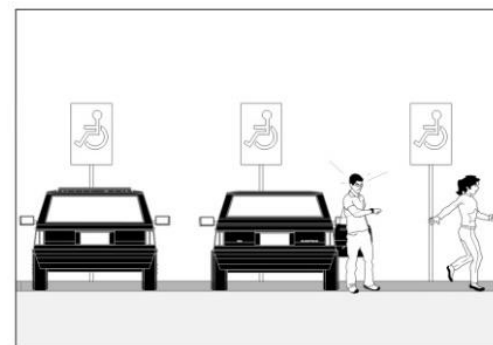
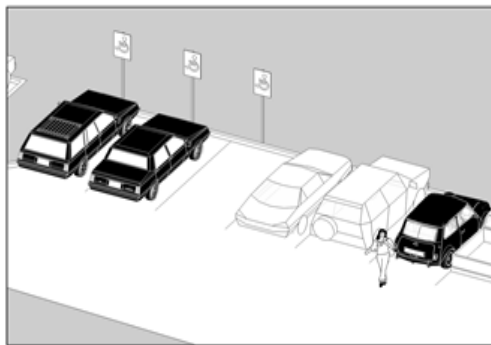
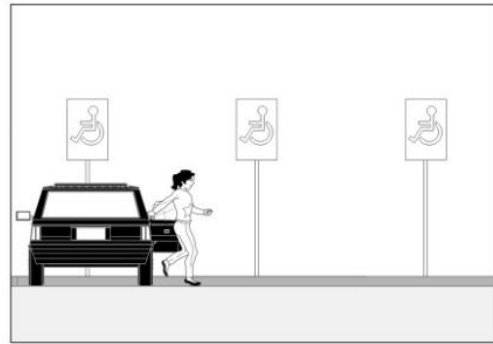
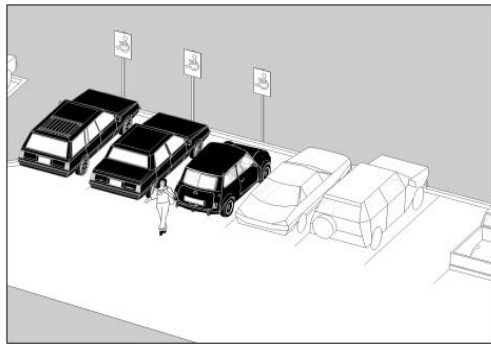
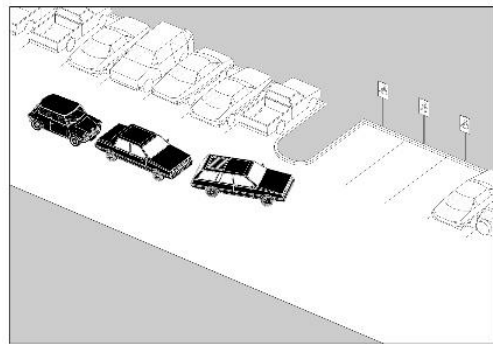
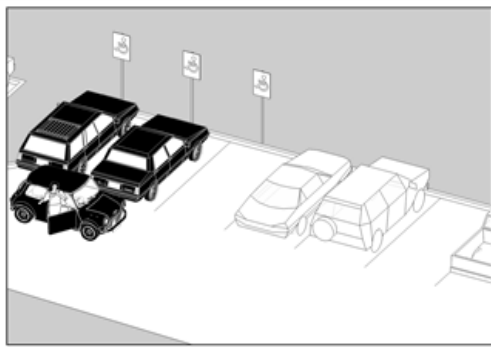
2- The pram moves and the old lady runs after the pram. (first false belief: What the old lady thinks is in the pram?) (Moral reasoning: taking into account the old lady is trying to save the baby – is this good, acceptable or bad).

3- At the end to assess second false belief I say, “Let us assume this story happened in a slightly different details”, then I display the second part of the task. The characters at the beginning of the scene are similar to the first part; the man goes inside the shop holding the baby and the mother remains outside looking at the vitrine, but the old lady appears in the scene before the mother puts her bag inside the pram. The old lady saw this but the mother did not notice and continues staring at the vitrine; then the pram moves and the old lady runs after the pram and the mother sees the old lady running after the pram, the I ask, “What does the mother think that the old lady thinks is in the pram?” – a “second false belief question”



3- Second Scenario: the old lady was standing there while the mother was putting her bag inside the pram, but mom did not see the old lady at first, then mother sees her. (second false belief): what does the mother think that the old lady thinks is in the pram?

Appendix I-2: Moral Reasoning Task

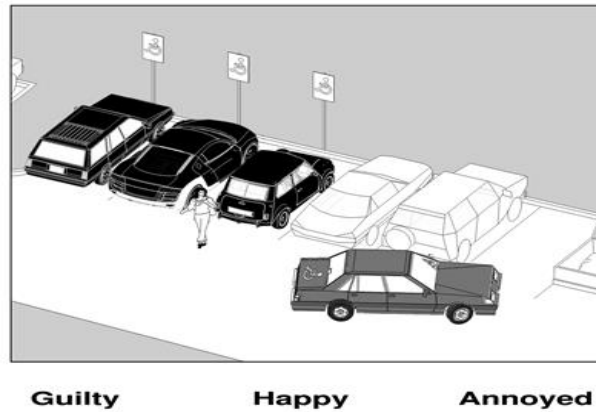


First set of three cards on the left are presented to the participant and the examiner.

Explains: Say there are three drivers trying to find a space in a congested car park, First car belongs to a healthy person, she decides to park in disabled space, second driver does the same. Now if you were in this situation, what would you do?

After answering own behaviour, the examiner presents the second set of three cards on the right. Saying we have three options for the third driver, what do you think the third driver ideally should do?

Appendix I-3: Emotional Empathy Task



When the participant chooses the ideal behaviour, a relevant car is shown to him and the examiner says: let's imagine the driver of the third car did the same as the others drivers did, namely, parking in a disabled place, and while she was getting away she sees a car belongs to a disabled driver had to go and find a farther space to park his car; now what do you think the girl will feel?

Appendix I-4: Intention Deduction Task



The first set of three cards on the left was presented to the participant and the examiner explained: these set of cards show a story; following the sequence of this story, if you were baking what would you do next? After giving a self-perspective answer, the second set of three cards on the right was presented and asked: Following the sequence in the story, what do think this woman will do?

Appendix I-5: Emotion Reading Task

amused

amused

kind

sad

surprised

afraid



angry

hateful

energetic

relaxed

happy

angry



afraid

comfortable

happy

disgusted



relived

pensive

disgusted

optimistic



sad

regretful

fearless

kind



Sad

afraid

fearless

relived

Appendix I-6: Desire and Motivation Recognition Task

Phase 1 Controlling self-perspective desire:



The participant was asked to see the activity/places displayed in each trial and say which one an old lady may prefer?

Mary prefers...



Phase 2 Desire question

Picture of the agent appears in the middle, first eye gaze to the left and right then the agent fixes her eye gaze in a specific direction. And we ask: what does the agent prefer

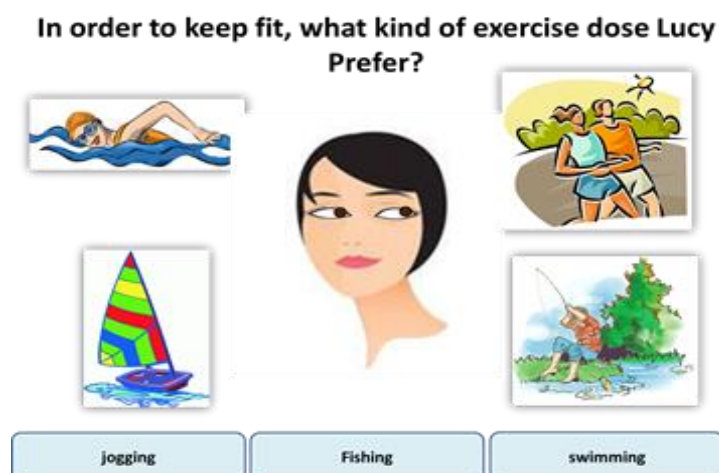
Phase 3 Motivation question



After answering the above questions, the participant was directed to choose one answer he/she thought reflected the motive behind the old lady's choice.



A sample of desire control trial



A sample of motivation trial

Appendix I-7: Psychological Attitudes Task

Samples of Psychological attitudes

Rate their attitude toward healthy food



0	1	2	3	4	5	6	7	8	9	10
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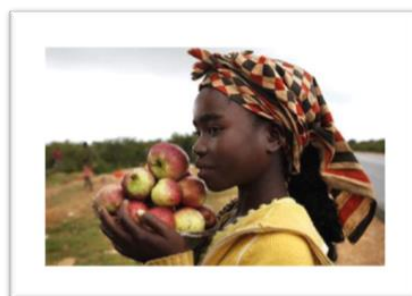
0	1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	---	----

Samples of Control tasks

Sample 1 Reorder the following pictures based on number of calories from high to low



Sample 2 Chose the correct answer; How many kilos do these apples weigh?



Less than a Kilogram

a kilogram

More than a kilogram

Appendix II-1: Proverb Comprehension Task

0- A bird in hand is worth two in a bush.	a. hunting
	b. risk
	c. opportunities
1- A friend in need is a friend indeed.	a. friendship
	b. importance
	c. loyalty
2- Blood is thicker than water	a. heart
	b. family
	c. friendship
3- As you sow, so shall you reap	a. cultivation
	b. time
	c. consequences
4- Facts speak louder than words	a. saying
	b. cheering
	c. doing
5- Do as you would be done	a. responsibilities
	b. action
	c. wishes
6- Cut your coat according to your cloth	a. sewing
	b. frugal
	c. payments
7- Easy come, easy go	a. going
	b. gaining
	c. losing
8- All that glitters is not gold	a. appearance
	b. metals
	c. deception
9- Birds of a feather flock together	a. quell
	b. affinity
	c. opinion
10- A tree is known by its fruit	a. offspring
	b. relationships
	c. leaves

Appendix II-2: Cognitive Empathy Indicator

14- I am good at predicting how someone will feel

15- I am quick to spot when someone in a group is feeling awkward or uncomfortable.

22- Other people tell me I am good at understanding how they are feeling and what they are thinking.

34- I can tune in into how someone else feels rapidly and intuitively.

35- I can easily work out what another person might want to talk about.

36- I can tell if someone is masking their true emotion.

38- I am good at predicting what someone will do.

Appendix II-3: Example of faux pas story

Kim's cousin, Scott, was coming to visit and Kim made an apple pie specially for him. After dinner, she said, "I made a pie just for you. It's in the kitchen." "Mmmm," replied Scott, "It smells great! I love pies, except for apple, of course."

Did anyone say something they shouldn't have said or something awkward?

If yes, ask: Who said something they shouldn't have said or something awkward?

(Comprehension question): Why shouldn't he/she have said it or why was it awkward?

(Comprehension question): Why do you think he/she said it?

(Intention question): When he smelled the pie, did Scott know it was an apple pie?

(Emotion Empathy): How do you think Kim felt?

(Control question): In the story, what kind of pie did Kim make?

(Control question): How did Kim and Scott know each other?

Example of a faux pas control story

Vicky was at a party at her friend Oliver's house. She was talking to Oliver when another woman came up to them. She was one of Oliver's neighbours. The woman

said, "Hello," then turned to Vicky and said, "I don't think we've met. I'm Maria, what's your name?" "I'm Vicky." "Would anyone like something to drink?" Oliver asked.

Did anyone say something they shouldn't have said or something awkward?

If yes, ask: Who said something they shouldn't have said or something awkward?

Why shouldn't he/she have said it or why was it awkward?

Why do you think he/she said it?

Did Oliver know that Vicky and Maria did not know each other?

How do you think Vicky felt?

Control questions: In the story, where was Vicky?

Did Vicky and Maria know each other?

Faux Pas Aphasia Version

2- Why shouldn't she have said it?

- Because she is her friend
- Because it was a surprised party
- Because Lisa likes Helen's dress

2-Why do you think she said it?

- She was trying to make Helen feel jealous
- I don't know
- It was a surprise party

2- How did she felt?

- Happy
- Disappointed
- Jealous

4- Why shouldn't she have said it?

- You shouldn't walk into a new apartment and criticize it.
- They were old curtains
- They were new curtains

4- Why do you think she said it?

- She liked the curtains
- She tried to hurt Jill's feelings
- She didn't realize they were new curtains

4-How did Jill felt?

- She felt fine
- disappointed
- I don't know

Appendix II-4: The Anger Indicator (AI)

- 1- I feel angry.
- 7- I feel angry about myself a good deal of the time.
- 9- My anger is so intense that I sometimes feel like hurting others.
- 11- I feel irritated a good deal of time.
- 13- My feelings of anger occasionally undermine my ability to make decisions.
- 15- My feelings of anger interfere with my capacity to work.
- 19- My feelings of anger are beginning to interfere with my health.
- 21- My current feelings of anger undermine my interest in sex.

Appendix II-5: The Abbreviated Apathy Evaluation Scale (AAES)

- 3- Getting things started on my own is important to me.
- 5- I am interested in learning new things.
- 8- Seeing a job through to the end is important to me.
- 12- I have friends.
- 13- Getting together with friends is important to me.
- 15- I have an accurate understanding of my problem.
- 16- Getting things done during the day is important to me.
- 17- I have initiative.
- 18- I have motivation.